



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

### Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

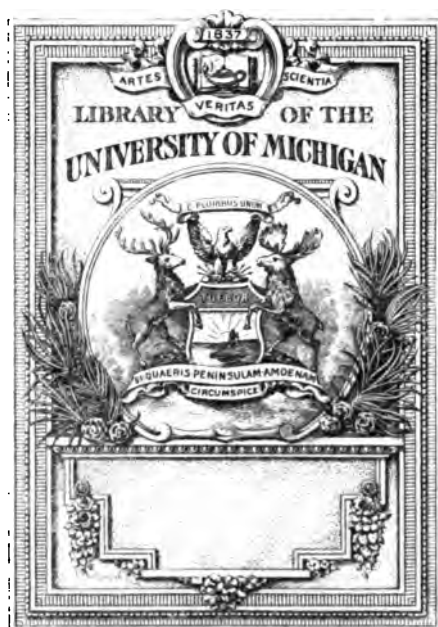
- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

### About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

OF THE  
EARTH





Q  
50  
B:



THE  
ROMANCE OF THE EARTH

101922

*Alexander*  
A. W. *William* BY  
BICKERTON

*Professor of Chemistry, Canterbury College, Christchurch,  
New Zealand University*



LONDON :  
SWAN SONNENSCHN & CO., LIM.  
PATERNOSTER SQUARE  
1900



## PREFACE.

---

In calling this little reading book a romance it must not be supposed that facts are ignored. I have used all the facts I found available. Most of the statements are the accepted truths, many of them the commonplaces, of science. Where I could not obtain facts, I have permitted myself to speculate, to make deductions from the accepted laws of nature. When I have thus soared on the wings of the imagination I hope the flight has not been unscientific, nor the views presented unsound. When I have used those wings I have kept well within sight of the reader; he can see every movement that has led me to these conclusions. Sometimes where no path existed I have not dared to soar; I have merely roughed out tracks that I hope will be straightened and metalled and become paths of progress. Where two opposing schools have suggested opposite ways I have not hesitated to use the clue given me by codified science, and have followed fearlessly where the accepted laws of matter and energy have led me.



A week at the British Association at Bradford will have shown how unsettled much of science still is. The tremendous discussions on Electrical Ions and on the Plants of the Coal Measures may be said to have ended in examination papers; and if my answers to two opposing schools do not satisfy both, I hope my final court of appeal, the reading public and their instructors the critics, will not "pluck" me, but will write the word "pass" after reading

THE ROMANCE OF THE EARTH.





---

# THE ROMANCE OF THE EARTH.

---

## CHAPTER I.

### THE EARTH'S MOTIONS.

A MASSIVE globe, about 8000 miles in diameter, is rushing forward in space at the rate of some twenty miles a second. The globe is nearly as heavy as though it were solid iron, and its speed is about fifty times that of a cannon ball. A piece of this globe equal in weight to a cannon ball would strike a blow of two thousand times the energy of the ball. Were this globe alone it would travel straight on in space. Its motion would be more direct than that of a rifle ball, for the latter moves in a curve and always tends to fall towards the earth. Our giant globe has a companion more than a million times its own size, and, like the rifle ball, it tends always to fall towards the larger body, and so it also moves in a curve. This tremendous projectile is the earth, and its

gigantic companion is the sun. The curve which the earth moves in is almost a circle, what is called an ellipse, and our globe takes a year to complete its round. Sometimes it falls a little out of its circular course, towards the sun, and the tremendous pull makes it get up speed, just as a great snowball goes quicker and quicker in rolling down hill. Presently the speed—and consequently the tendency to fly off from the centre—is so great, that the pull of the sun is unable to draw the earth any nearer; it is, as it were, at the bottom of the hill, thereafter it gradually loses speed, and climbs up another hill, so to speak, until it gets to its greatest distance from the sun—about 93,000,000 miles, a very much greater distance than we can think of clearly. Its headlong rush down hill had brought the earth about 2,000,000 miles nearer the sun than usual. This difference is not always the same. Sometimes there is as much as 13,000,000 miles difference; and then come into action wonderful changes which clothe much of one hemisphere with ice, a great glacial epoch making temperate countries into arctic.

As the earth flies onward in space it also spins like a top, and when one side faces the sun it is day on that side, and when it is away from the sun it is night. If we think of the curve in which the earth revolves as a hoop floating in still water, and if we imagine our globe a spinning globular top dipping

halfway through the hoop, its axis will appear not upright but tipping over a good deal. If it tipped over four times as much, its axis would lie on the surface of the water. This surface corresponds to what is called the ecliptic, because it is when the moon is in this plane that we have eclipses.

The moon is a body about fifty times less than the earth, and it revolves around the earth in twenty-eight days. Its orbit, that is, the circle it travels in, does not lie in the ecliptic, otherwise the moon would get between us and the sun much more frequently than she does—every new moon we should have an eclipse of the sun. A fortnight later the moon would be immediately behind the earth, and away from the sun, and every full moon we should have a lunar eclipse. The moon's orbit dips slantwise through the plane of the ecliptic, and so it is only occasionally that the sun, moon, and earth lie in a straight line, and we have an eclipse.

The fact that the earth spins with a leaning axis causes the seasons. If its axis tipped right over into the ecliptic, at one time the sun would blaze square upon one pole: and six months later, square upon the other. But, as it leans a little only, at times the sun shines slanting upon one pole, and six months later it shines upon the other pole, and we have the arctic and antarctic summers. Nearing the equator we come to a point where at midsummer the sun shines

directly overhead. The most northern circle traced round the earth by this vertical sun we call the Tropic of Cancer. Sometimes great pillars have been built and deep wells dug on this circle, and when the pillar casts no shadow, or the sun blazes directly to the bottom of the well, it is twelve o'clock on midsummer day. Many such pillars are of great antiquity, showing that the ancients were acquainted with some of the important facts of astronomy. Midsummer day being past, the vertical sun gets nearer and nearer to the equator, and in three months it is overhead at the equator, and we say the earth is at its equinox; for all over the globe the days and nights are equal. Other three months elapse, and the southern limit of the vertical sun is reached, the Tropic of Capricorn. In three months the sun is back again to the equator; so we see that the equator has two summers a year, and everywhere within the tropics the sun is right overhead twice a year. The earth and its moon are not the only companions of the sun; there are eight true planets, four small ones near the sun and four large distant ones. The two sets are divided by a belt of hundreds of companions called planetoids. The earth is the third planet reckoning from the sun.

On the earth, within the tropics, the heat of the vertical sun causes great evaporation, that is, the water changes from liquid to vapour, and forms

moisture in the air. This moisture, being carried upwards by currents of ascending heated air, is chilled by expansion at great heights, and descends as rain. These torrents, combined with the heat, help to bring about the profuse vegetation of the tropics, and the vast numbers of beasts of prey, reptiles, gorgeously-plumaged birds, and wondrous insects add to the impression we get of luxuriant growth and teeming life. The poles, on the contrary, are covered with perpetual ice, and there is much less life there (see Frontispiece). At the poles, the sun is below the horizon for six months; then its upper part circles round, showing itself between the hills in the low valleys. Next, more of the disc appears, then it circles completely round the horizon. Getting above the hills, it travels slowly upwards in a continuous spiral till it reaches an angle of  $23\frac{1}{2}^{\circ}$  from the horizon; then it spirals down again, ever in sight save when some cloud obscures it. Thus, for six months, there is no night, and a scanty vegetation struggles into brief life. Leaving the poles, we come to circles on the globe where, at midsummer only, the sun may be seen continuously for twenty-four hours, giving us "the midnight sun." This we call in the north the Arctic Circle, in the south the Antarctic Circle. Travelling towards the tropics, we find that the inequality between summer and winter gradually decreases, so that between northern New



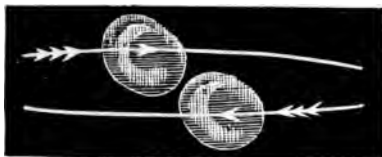


Fig. 1—Pair of stars distorted and coming into impact.



Fig. 2—Pair of stars in impact.



Fig. 3—Stars passing out of impact, and formation of third body.



Fig. 4—Showing entanglement of matter in each body.



Fig. 5—Two variables and a temporary star.

Diagram of the partial impact of a pair of stars or dead suns producing a pair of variable stars and a temporary star, example Nova *Antares*.



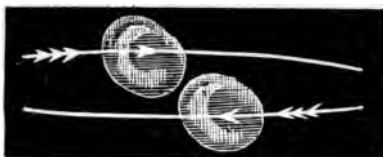


Fig. 1—Pair of stars distorted and coming into impact



Fig. 2—Pair of stars in impact.



Fig. 3—Stars passing out of impact, and formation of third body.



Fig. 4—Showing entanglement of matter in each body.



Fig. 5—Two variables and a temporary star.

Diagram of the partial impact of a pair of stars or dead suns producing a pair of variable stars and a temporary star, example Nova Aurigæ.

## CHAPTER II.

### THE BEGINNING OF THE EARTH.

**W**ONDERFUL are the changes brought about by the many motions of the flying earth ! How complex they are ! Our planet rotates on its axis, which causes day and night. It revolves in its orbit, in a leaning position, which produces the seasons. The pull of the moon and sun on the leaning top causes the axis to rotate conically, and this motion it completes in about 26,000 years, the motion being styled the precession of the equinoxes. The pull of the moon makes it sway backward and forward in its orbit ; and this pull has to do with the tides. The pull of the other planets alters the eccentricity of its revolution, so that the sun is sometimes much farther from the centre of its orbit than at present ; and this variability, combined with the conical motion, causes rhythms of arctic and tropical climate, called glacial periods, which have produced extraordinary changes in the history of living creatures upon the earth.

Turning from these great changes to contemplate

the earth's surface, we see a tumult of life, of struggle and conquest, of birth, maturity and death, of organisms and their parasites, and the parasites of parasites. The microscope shows the seemingly inert soil of the field to be teeming and seething with the most varied life; it exhibits a drop of stagnant water as a world of wonders. The profusion of variety and the complexity of detail seem at first to have no limit. Among insects alone the different kinds or species are numbered by hundreds of thousands. Nor is there only variety due to place, but also variety due to time. Go back a tick of eternity's pendulum, and the life clothing the earth is altogether unlike its present vesture. There are no marks of man's hand upon the earth, for man does not exist. Another tick—the flowering-plants and the mammals are not on the scene; huge reptiles swarm amid the forests of club-mosses, ferns, and horsetails. Still another tick—the sunlight has not begun to use the green colouring matter called chlorophyll to split carbonic acid asunder, and thus there is no vegetation at all. Further back, the earth is a great red-hot cinder; further again, a molten ball surrounded by a dense, flaming, gaseous atmosphere.

Now, let us skip a few million years and consider the earth as a member of one of the parent systems from which, by impact, our own solar system originated. Perchance many planets belonged to

that old-time system. Almost certainly they did not revolve in a plane, but moved at all angles and in all directions; in an order beautiful enough of its kind, but not the order of our present system. Imagine an old-time astronomer watching from the then earth the erratic movements of another planet! He is startled by its being out of place; some unknown sister would, perhaps, account for this; but the variation is too sudden and too great. Is it a dead sun, or a small, burnt-out star cluster that draws near? He tells his fellow-observers, and presently every one is at work. By the movements of all the planets it becomes certain that another orb is coming. Will it collide with the earth—with some other planet—may it graze the sun? Presently some of the stars are eclipsed by the dark body. Now, with reflected solar light, it begins to glow, as a distant planet. Now, its orbit can be figured out. It will graze the sun! It will be nearly a half graze. A new sun will be born—a fiery nebula produced that will envelop the earth. The old order is over, and, as a sum is sponged from a slate, so life is swept from the globe.

What was the nature of the two colliding bodies that gave birth to our solar system? Our imaginary astronomer can give us no information; we can only conjecture. For possibly no cosmic problem offers so fertile a field of inquiry as the impact of celestial

bodies. If the paper in the August "Philosophical Magazine" on Cosmic Evolution represents the truth, as a vast mass of evidence seems to show it does, then impact is the Promethean spark that gives life to decaying worlds and systems. The frontispiece of this chapter gives an idea of an impact that is a mere graze; a brilliant spark has been produced by the colliding part of the dead suns as they swept past each other. Such is probably the phenomena that produces the new stars that occasionally burst forth suddenly with great splendour. But the new star is too hot to be stable; each molecule may have velocity enough to carry it entirely away into space to help in the formation of new and distant universes. The brilliant, flaming mass expands first into a hollow shell of gas called a planetary nebula, and then dissipates altogether. Nova Aurigæ was the first temporary star whose triple constitution was demonstrated. (See Frontispiece Chapter II.) When instead of a mere graze the bodies plunge deeply into one another, then they join and whirl around one another; and it is to such a whirling collision, it is suggested, the solar system owes its genesis. Let us imagine the stupendous flash of the grazing collision to have passed; the planets have been swung by centrifugal force into a plane—as a twirled mop disperses its drops of water, or a Catherine wheel its sparks of fire. The planetary bodies fly in curves

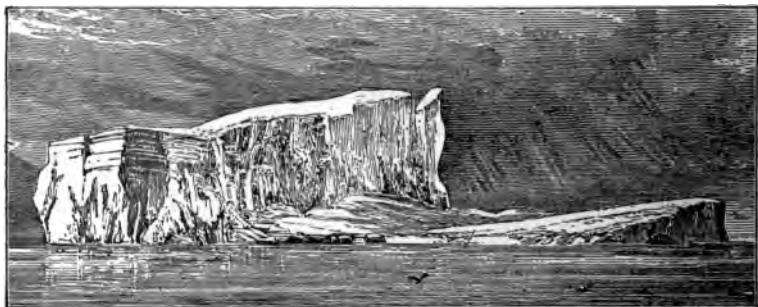
almost directly from the centre, but the pull of the central mass slowly stops them, just as the pull of the earth stops the upward motion of the ball thrown in triumph at a cricket match. Then they recurve towards the denser portions of the nebula. But countless agencies are at work to alter the curves of their orbits. Let us try to understand one of these.

Suppose a cup and ball with an elastic cord. You throw the ball, and the pull of the cord brings it back. Now you throw so hard that the cord breaks; the ball does not come back, the attraction is gone. Suppose you throw a cricket-ball upward. Imagine the earth suddenly to disappear—the ball will not return; it will travel straight on in space. Now think of our earth: it was swung off; it has curved over; it is returning. But suppose the nebula has expanded so much as to be largely outside the earth's orbit; the part outside will not be pulling it back. If half were outside, the earth would not tend to return; it would revolve in a circle; hence the planets' highly elliptical orbits became approximate circles, and so, by this agency and by many others, the order of the solar system grew up. Our earth is an inner planet. In plunging into the fiery gaseous mass, it loses its light gas and picks up heavy molecules, and, so loaded, it cannot run away. It is a heavy gaseous body, revolving in a nebula. It picks up endless smaller bodies; presently a larger



mass plunges through it and gets entrapped—the earth has caught its moon.

As the solar nebula shrinks it leaves the earth outside, and the earth in its revolution in the surface of the nebula picks up its water and its atmosphere. In the earth's daytime the flaming sun covers its entire sky. Still the nebula shrinks, until Venus emerges. Now the sun is a fire covering the whole

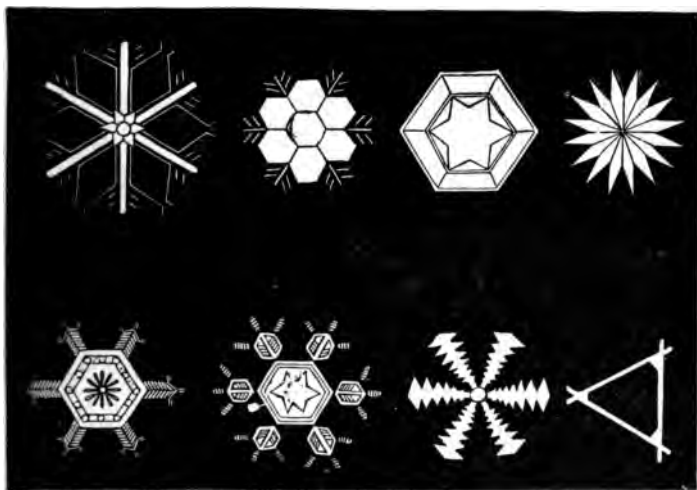


*Fig. 1.*—ICEBERG SEEN ON 21ST FEBRUARY, 1874, FROM "THE CHALLENGER."

area within the orbit of Venus. Another æon, and Mercury emerges.

But, while the sun is shrinking, wonderful changes are occurring in the earth itself. The gaseous mass has become liquid, and the liquid cools on the surface and sinks, while the hotter molten material rises up from below to take its place. A circulation is thus set up that tends to cool the liquid rock to its limits.

Some of the rock gradually begins to solidify on the surface and to sink. For rock is the reverse of water; water solidifies, expands and floats (Fig. 1); rock matter solidifies, contracts and sinks. The molecules in the lovely ice crystals (Fig. 2) are not packed tight like bricks in a box—the crystals are structures to



*Fig. 2.—FORMS OF SNOW CRYSTALS.*

some extent hollow. Pressure tends to fill the spaces, to crush the crystals; in other words, to make the ice into water. But rock, when it solidifies, contracts; so, when the molecules are rigidly locked into the solid state, pressure tends to keep it solid.

As the rock sinks it is subject to pressure, and

may remain solid; but it is also subject to intense heat, and may become more or less soft or plastic, or it may melt in such fervid temperature. The centre of the earth is probably composed of dense metals, like gold, platinum, lead, and mercury. Their density would limit the sinking tendency, so that the crystals of rock would float on the surface of the molten metal and gradually silt up the lava ocean, in places reaching to the surface. The space between the crystals would still be filled with molten matter, and —when the silting reached the surface—this would also begin to solidify. This silting up would be very uneven, and molten lakes would be left which would afterwards cool, solidify, and shrink, producing vast hollows — perchance our present ocean beds. Eventually the crusts would join and coat the earth with a continuous white hot shell.

In the far back epoch we are thinking of, the carbon of the planet is probably not yet in a solid state. It is possibly all combined with oxygen as carbonic acid gas. The base of the limestone rock is still caustic, not carbonate, the date of the coal measures is still in the distant future. Some of the earth's salts and most of its chlorides are in a state of vapour, gradually condensing on the poles and other cooler parts, falling here and there as molten saline rain, and flowing as glowing lava streams into molten lakes to be boiled off again. Possibly showers of

meteorites contribute towards inequalities of temperature. By-and-by, the salt is solidified, and water begins to fall as rain on the poles and other cooler regions, forming boiling lakes; some parts are still too hot for this, and the raindrops fall, to dance up again as quivering spheres buoyed up on their own steam. To boil water requires heat; thus the boiling arctic and antarctic seas cool the poles, and thus the rocks shrink and become denser, tending to sink under the increasing weight. As the water stands where the molten saline lakes solidified, it dissolves the saline matter, and the sea becomes salt.

## CHAPTER III.

### THE MAKING OF THE EARTH'S CRUST.

THOUGH it is by no means easy, it is worth trying to gain a living picture of the way in which the surface of the earth came to be what it is. First, the crust cools, shrinks, gets too tight and splits; then the cool crust becomes too big for the contracting interior, so that it crumples up and breaks. All the while steam explodes, and torrents of boiling water, bearing *débris*, rush in tumult over the surface. Then, owing to the great world-changes already spoken of, ice accumulates alternately upon either pole and pushes forward upon the polar hemisphere; consequently the centre of gravity of the earth is altered, and the water is dragged to the icy hemisphere, while the opposite hemisphere is left almost dry land, with an equably temperate climate. After a long time, vegetation begins to clothe the surface, modifying all the other agencies. Evidently, while considering such a conflict of forces, we need patience as we try to thread our way through the labyrinth, with its many tortuous twists.

Although, in comparatively early epochs, the poles of the earth would, doubtless, be slightly cooler than the other parts, we must remember how water and carbonic acid oppose the penetrating power of the sun's radiant heat, so that the equator would not be much hotter than the poles. Think of all the water of seas and lakes, and all that is now contained in plants and animals, and in crystals—think of all this water existing as steam in the atmosphere along with the enormous quantities of carbonic acid not yet absorbed or decomposed! An atmosphere surpassing our own many hundred times! The sunlight would scarcely penetrate such dense clouds as the upper regions of that atmosphere would present; and, even if it did penetrate, it would be “refracted” or curved round the poles, so that polar cold would not be an important factor in producing condensation. Pressure alters the temperature of boiling water; in a perfect vacuum ice-cold water will boil; so that imagine the high temperature of the steam and rain under the pressure of an atmosphere many hundred times greater than ours now is—equalling tons to the square inch! All these agencies would tend to produce a general equality of temperature, yet minor irregularities would appear, and in the cooler places the raindrops would spread over the surface, and the water would flow as boiling streams, combining into torrents—possessing the great dissolving power of

boiling water at high pressure—bearing rocks, silt, and *débris* of all kinds. Nor must we forget that to boil water requires much heat (we know how it cools red hot iron); hence, where the boiling water stood its cooling influence would contract the crust and tend to flatten its curve, that is, to bulge in the earth's surface, thereby forming deep depressions, wherein still more water with sedimentary and dissolved material would gather. When a mass is above what is called the "spheroidal point" it takes a long time for water to cool it—the steam keeps the water out of contact. In my boyhood, I saw a huge mass of white-hot iron being carried up the railway on a trolley crane. I followed and saw the men stop at a bridge and lower the mass into the river. There, beneath the water, hung the glowing iron. The surface of the river became a maelstrom; it boiled and bubbled, and at times the water seemed to burst away from the iron. The noise was most remarkable, yet, amidst it all, the block continued to glow. It became tedious to watch its light. The men moved the trolley backward and forward, yet still the mass glowed and grumbled. Then, after an hour or so, it began to blacken and hiss; and so it gradually cooled till it was fit to be handled.

Besides local changes, the whole crust of the earth was cooling and contracting, causing extreme strain and exerting a tremendous pressure upon the interior,

so that immense splits would occur. Clearly these splits did not take place in the thick crust underlying the water areas; they occurred in the thinner crust of the dry areas, and vast ridges of molten rock poured out and out—for the contents of these splits would remain softer than the rest of the crust, and would be, as it were, safety valves allowing escape of molten rock matter. (Fig. 3.) This would go on until the super-

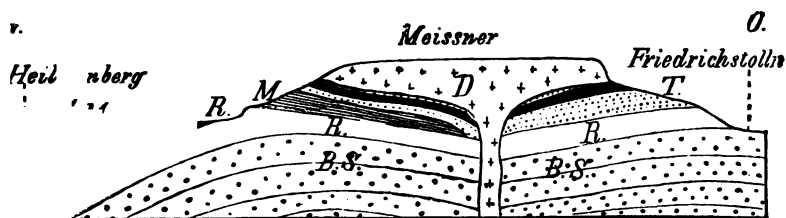


Fig. 3.—SECTION SHOWING EXTRUSION OF MOLTEN ROCK.

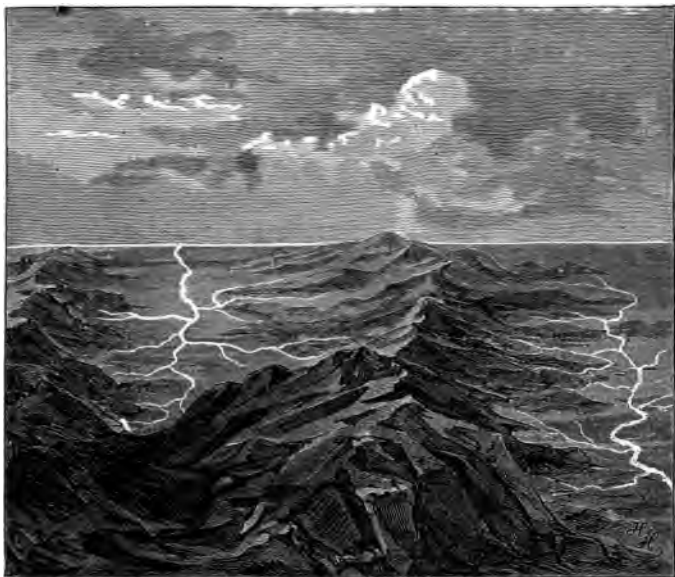
incumbent mass was so immense that its tremendous weight depressed the white-hot dry crust, which would sink below the level of the lakes, bulging their floors up and causing the water to overflow into the hot areas immediately alongside the great volcanic ridges. Again came the boiling and cooling, again the density of the crust increased; and, as time went on, this alternate action would extend over larger and larger areas. The lakes would become seas, and the seas oceans. The smaller areas of dry land would enlarge to continents, and the continents would sink until the continental areas were oceans and the oceans



dry land. Imagine the effect upon the atmosphere when the waters of the ocean rushed in about a white hot volcanic ridge, thousands of miles long; pouring into the innumerable fissures, becoming high pressure steam, exploding and throwing the rocks scores of miles high! From the whole ridge would rise an uprush of steam and air. This would be affected by the earth's rotation, just as our trade winds are now affected by it, only in a tremendously exaggerated way. Awful tornadoes would occur, and the rainfall would be altogether beyond our conception.

I have seen a storm in the Otira Gorge in New Zealand; but what was that to the possibilities in the early volcanic period of the earth's history! The rainfall of such storms would be estimable, not in inches, but in hundreds of feet. Yet a few inches produce effects almost incredible. In the Otira storm the rain seemed to fall in sheets. Immense cascades began to gush from the mountain sides where no sign of even a rivulet had appeared before. From higher and still higher points the cascades started forth, shooting out of the dense forest thousands of feet aloft, leaping over the tree-clothed mountain side clear to the gorge below. Great trees trembled, swayed, and fell with a mighty crash upon their comrades. The volume of water in the Otira swelled prodigiously. Huge boulders—big as waggons—in the course of the torrent, became undermined, they

trembled and toppled over, releasing other smaller boulders—smaller, yet tons in weight; and these were carried on, to jam, and enclose small lakes; presently to be in motion again, suddenly liberating



*Fig. 4.*—WATERSHED.

The hollow trough which holds the water of a river is called its bed. The district drained by a river and all its tributaries, is called its basin. The boundary line between two river systems is called the watershed, or the line of water parting.

the water, which rushed forward with the roar of a bursting reservoir. In two days we were able to resume our journey. But how changed the road!

The macadam was washed away to the bare rock ; in places the very direction of the road had to be altered. (Fig. 4.) This figure shows the carving of the earth by water.

What must have been the gouging and grinding power of these primitive torrents ! Think of the rainfall resulting from the steam and vapours in the atmosphere, equivalent to a mile of water covering



*Fig. 5.—DELTA (NILE).*

the entire earth ! What enormous masses of sediment such erosions would send to the bottom of the oceans are shown by the immense deltas of our great rivers. (Fig. 5 is an illustration.) With moisture in the atmosphere so enormously greater than now, the time came when snow could fall on the poles, and tremendous glaciers—smoothing and sculpturing the earth—

would be formed. Then, again, owing to the conical motion of the earth's axis, and to the eccentricities in its orbit, alternate torrid and frigid climates would follow each other over and over again from hemisphere to hemisphere. As the earth cooled, more and more water would be deposited, and the alkaline and other metallic oxides, especially the soluble ones, such as lime, would combine with carbonic acid, and be deposited as carbonates. The torrents of hot water, bearing heavy rock and *débris* of all kinds, would be powerfully erosive, and the eroded matter, as already suggested, would tend gradually to cover the ocean's bed with sedimentary rocks. These, in very thick deposits, would be subject to extreme pressure and to heat from the interior, and would be converted into what are called metamorphic or altered rocks, like quartzite—which seems to have been originally a sandstone. (Fig. 6.)

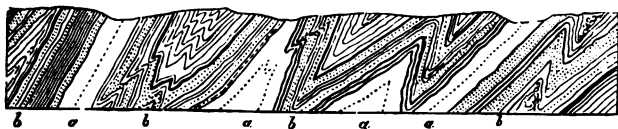


Fig. 6.—SECTION THROUGH THE ARCHAEOAN AT GRENVILLE IN CANADA (LOGAN).

a Crystalline limestone; b gneiss and quartzite.



**LEPIDODENDRON STERNBERGI (Restored).**  
Forty feet high. Coal Plant.

## CHAPTER IV.

### EARTH-SCULPTURING.

AS the temperature of the surface of the earth sinks, a new action comes into play. The cooling and contraction of the crust becomes slower and slower, until the internal part is cooling by conduction almost at the same rate as the external part by radiation. The atmosphere has greatly decreased, most of the water is deposited, much of the carbonic acid has become fixed; the sun's rays are, therefore, becoming more able to penetrate to the surface of the globe. The sun has diminished exceedingly in size, while its temperature has proportionately increased; for, remarkable as it may appear, the more heat a gaseous world gives out, the hotter it grows. As it shrinks, the pressure resulting from the increased gravitation reduces the internal layers to smaller and smaller bulk, thus causing a tremendous increase in the quantity of heat. A gaseous sun, in becoming compressed to one-half its volume, gives off enormous quantities of heat, yet it

is double the temperature when it has shrunk to one-half the diameter.

Heat whose source is at a very high temperature can penetrate gases and vapours much more easily than heat from a comparatively moderate source. Hence from these two causes much more heat reaches the crust of the earth, and retards the lowering of its tropical surface temperature. A time ensues comparatively free from volcanic and earthquake disturbances, and at this stage—during a glacial period—it is probable that the earth became cool enough in places to permit plant life to commence at one of the poles. How this may have occurred we will discuss further on. At present we must be content to take a rapid survey of the physics of the earth's crust.

We have traced the molten earth in its process of cooling. We have taken an imaginary glance at the solidifying of the surface, and have seen how, by the hardened rocks sinking down, this solidification would extend to great depths. We have noted that, when solid, the surface would tend to cool more quickly than the interior; and how, shrinking and exerting enormous tension and pressure, it would split, and the interior would be forced out in a molten state; the heat producing this state being largely the energy of the pressure itself. We have traced the oscillations of levels which water and the deposit of sediment would produce, and then the gradual reduction of the

temperature of the surface, until solar heat would tend to retard surface cooling, and external and internal contractions would proceed at almost equal rates. A period of comparative quiet would ensue. Then, after a time, the gain of heat from the sun would balance the surface loss, and the crust would cease to cool and contract. Now a new order of events begins to operate. The hot interior loses heat by conduction through the crust, and continues to shrink, while the crust gets to be too

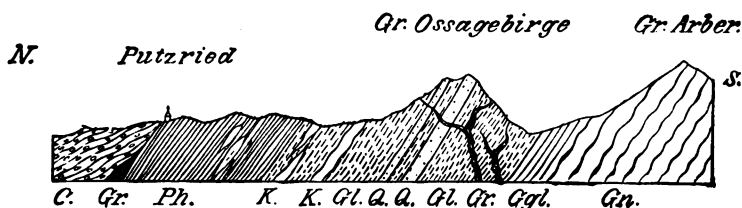


Fig. 7.—SECTION THROUGH A PART OF THE BAVARIAN HILLS (GÜWHET)

Gn Gneiss; Ggl Dyke of Gneiss in Mica Schist; Gl Mica Schist; Gr Granite Dyke; Q Quartzite Schist; K Granular Limestone; (Ph) Phyllite; (C) Cambrian.

big for the contracted contents of the globe; and, just as the loss of water from a shrivelling apple causes the surface to wrinkle, so the shrinking interior of the earth must cause its surface to crush and wrinkle, and a second period of convulsions ensues. During this time great earthquakes would cause the whole earth to shiver, as the rigid crust crumpled up in its efforts to fit the contracted interior (Fig. 7 shows the effect of this action in almost



tilting strata on end.) More and more slowly would the heat pass from the interior until the comparative quiet of the present period was reached.

Thus, then, there are two great agencies producing volcanic action. First, the cooling of the solid crust being more rapid than the internal cooling, the surface shrinks and splits; then, after a pause in the paroxysms, the crust ceases to cool and contract, whilst the continued cooling and contracting of the interior cause it to shrink away from its crust, and the crust begins to crush and crumple to fit its contracted interior.

Probably it was during the interglacial periods occurring in the pause between the earlier volcanoes of surface tension and the later volcanoes of surface crumpling that the enormous forests of the carboniferous period clothed wide regions of the earth and formed our chief coal formations; storing up the solar energy of those far-gone ages to supply man in this present period of conflict and unrest.

Thus the earth has passed through its period of tight crust and splitting to a period of quiescence, and now we must consider in detail how the tight crust has to wrinkle and accommodate itself to its shrinking interior. Apparently inextricable sets of agencies are put in operation by the crumpling of the earth's surface. Let us try to disentangle some of them. Owing to the inequality in thickness and strength of

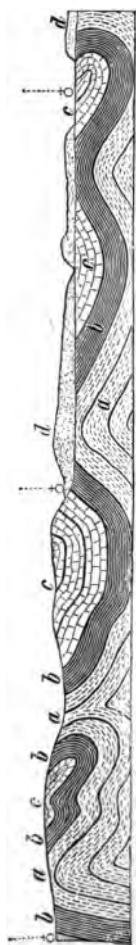


Fig. 8.—SECTION THROUGH A PART OF THE SCHIEFSRGEHIGE OF THE EISEL (BAUER), SHOWING CRUMPLED STRATA.

*a* Older Lower Devonian; *b* Later Lower Devonian; *c* Middle Devonian; *d* Bunter Sandstone.

the crust, the chief crumpling would take place in the weakest parts; often, probably, the margins of continents. Sometimes the earth's surface would buckle up so much as to form mountain ranges (Fig. 8); then, along the tops of these new ridges immense splits would open that would become wider and deeper as the crumpling continued; rain would fall upon the rents and torrents rush down them; so the fissures would become valleys. Along the far-dissevered sides of some of these mountain valleys the rock strata, once continuous, may be traced at the present day for miles. Sometimes the efforts of the crust to fit itself to its shrinking contents would produce such tremendous pressure as to heat and fuse the rock; the molten substance would find vent and volcanoes be produced; the hot erupted matter would melt the sides of the outlets and form, in time, circular craters overflowing and forming the slopes of great

volcanic cones. As each outrush was exhausted the matter in the vent would solidify and the crater become a reservoir to catch and hold water, which would boil off and so rob the glowing rock of its heat. By-and-by, the pressure would renew itself, again bursting through all obstacles in tremendous eruption; but before the upward pressure exploded through the bottom of the crater, the whole of the original walls of the volcano would be split by fissures radiating from the vent. Into these fissures the fresh molten matter would flow, forming volcanic "dykes."

Many of our mountain chains have been produced by the crumpling and bulging of strata; but, in other cases, the stratified rock material has probably been thrust by lateral pressure up the mountain ridges, produced ages before by the great splits of the primitive volcanic period of tension.

But of the complications of earth-sculpturing agencies there appears to be no end. In addition to the two volcanic periods of tension and pressure and the erosive action of boiling torrents, there came into force—as soon as snow could fall upon the earth—another tremendous factor in modifying surface conditions, namely, glaciation, or the results of ice. Snow would settle on the poles and accumulate there; it would cap all the higher mountains and gradually spread downwards, advancing from the poles toward the polar circles. An astronomic

influence of surpassing potency must here be considered. The orbit of the earth is an ellipse—an ellipse may be seen in a hoop leaning a little away. Generally the earth's orbit is nearly a circle, but sometimes, owing to attractions of the other planets, it becomes a long ellipse, the sun being at one of the foci, that is, near one of the smaller curves of the orbit. In extreme cases the earth may be 13,000,000 miles nearer the sun at one part of its annual revolution than at another; at present the difference is only 2,000,000 miles. Now, summer is not due to promixity to the sun, for we may be nearest at midwinter. The seasons are caused by the leaning of the axis of the earth. In the summer hemisphere the axis leans toward the sun, and the directness of the rays causes the high temperature. Winter is caused by the axis leaning away from the sun. It is clear that if during, say, the south polar winter, the earth happens to be 13,000,000 miles nearer the sun than it was six months previously, the southern winter will be very mild; but six months later, when the earth has receded 13,000,000 miles from the sun, the winter of the northern hemisphere will be very cold indeed. In that cold winter most of the water will fall as snow instead of rain, and the snow will pile up on the pole, while the summer sun—instead of warming the surface of the soil—will be engaged in melting the snow. The heat may no

suffice to do this completely, and next winter will increase the mass of snow. If this accumulative process lasts—as it may—for 13,000 years, the polar snow may creep down into temperate regions, and such a vast cap of ice be produced as to alter the centre of gravity of the earth, so that one hemisphere may have nearly all the water as ice and sea, and the other may have an almost entirely land surface. One polar hemisphere, the oceanic and icy one, will be nearly all frigid, while the other, the continental, will be very temperate, the seasons being almost equable, the summers cool and the winters without frosts quite to polar regions. Thus, organic life, both animal and vegetable, will increase prodigiously.





GLACIER (Roselg, in the Bernian Alps).

## CHAPTER V.

### ICE AGES.

A GLACIAL epoch lasts, roughly, a hundred thousand years, and two such epochs may follow close on one another. But every 13,000 years the tilt of the earth reverses itself, and opposite poles have mild winters; the ice-cap melting from one pole and forming on the other. There may be several glacial periods in one epoch; for instance, Europe may be for 13,000 years sub-tropical, then, for a like period, arctic; and so on till the time of the epoch is exhausted. In some of these great glacial periods the ice sheet covered Europe. Vast glaciers stretched from the high land of England far out into the Atlantic; in many parts, as the ice was thrust forward hundreds of miles, being lighter than water, it would tend to float; the upward pressure would break it, and huge icebergs would become detached, which, floating farther south, would carry the arctic climate still nearer the tropics.

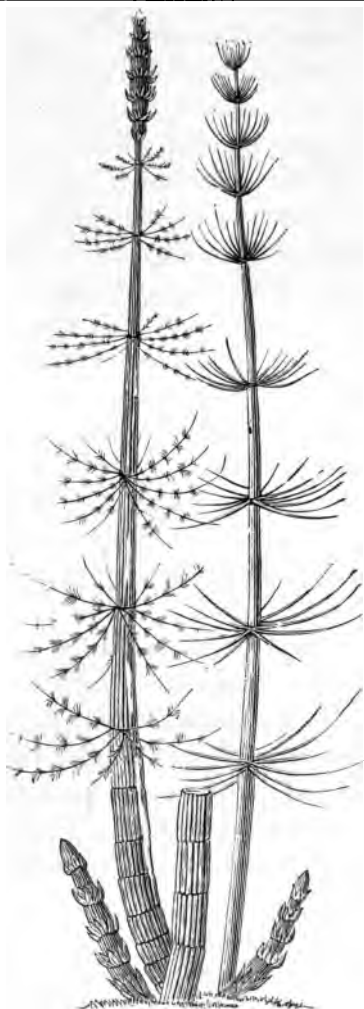
In our time the southern hemisphere is colder than the northern, but the earth is almost at its least



inequality of distance from the sun, and the difference of polar temperature compared to that of a glacial epoch is slight. The winds are now chiefly the result of the uprush of air caused by tropical heat. The area of this uprush travels with the summer alternately into the northern and southern hemispheres; and the vertical sun in crossing the equator alters its latitude quicker than at any other time; so, by this rapid change of latitude of uprush, we get, in spring and autumn, the equinoctial gales. At midsummer, in either hemisphere, the vertical sun seems to remain almost stationary; we call this time the solstice, that is, the sun standing still. Then for some weeks the medial line of aerial uprush changes but little, and we have a period comparatively free from violent storms. What will happen to this medial uprush in a glacial epoch? Clearly, it will travel away from the icy regions. Now, ocean currents follow winds, hence the equatorial water will be driven into the warm hemisphere, melting the polar ice, and rendering the earth habitable well within the polar circle; sometimes, possibly, in extreme cases, quite up to the poles. In this way the Gulf Stream of our own period warms north-western Europe and fits it for human habitation.

The warm equatorial water being drawn from the chilled hemisphere, causes it to be still more icy; thus many cumulative forces are at work that greatly

accentuate the oscillations of climate during a glacial epoch. Many thousands of years of equable temperature clothe the land with vegetation: then, gradually, during long ages, the climate changes, and cold intensifies until ice piles high where plants had luxuriated; and so, as the tilt of the earth's axis reverses itself, vegetation alternates with ice over and over again. In all directions the strata of the earth prove to us the wonderful vicissitudes of climate produced by these epochs; as, for instance, when we find fossil palms and tree-ferns over and underlying ice-scratched boulders and other remains of glaciation. We may imagine the effect of the encroaching arctic climate on the animal kingdom. How the polar mammals, like the bears, would rejoice in their extending area! How the tropical reptiles would wriggle towards the equator! How the gorgeously-plumaged birds and gaily-coloured insects would take flight in the same direction! Then, again, we may picture—with tropical climate slowly creeping back—the pines and arctic plants receding up the mountains, and the woolly rhinoceros and the mammoth retreating toward their polar domain once more! Think of the melting ice; the advance of tropical animals and plants to previously temperate regions, of temperate denizens to the arctic world; the entire hemisphere richly verdant—with small oceans, and these in the deeper channels only!



*Fig. 9.*—COAL MEASURE PLANTS.  
*Calamites* sp. ; restored (after Scheuk), greatly reduced.

I have already suggested that it was in the pause between the volcanic period of surface tension and that of surface crumpling that the coal measures were deposited. There are many reasons for the belief. The earth was warmer than at present, and the air held more water and more carbonic acid. Geologists, in describing the carboniferous age, tell us of monotonous plains, thousands of miles in extent, relieved by scarcely a hill; a continuous swamp with a dank vegetation (Fig. 9), and uncouth creatures crawling amidst it. Such conditions exactly correspond with the period of rest. The crumpling of the earth had but just begun. Great part of the early inequalities had been eroded away, leaving immense plains bounded by huge mountain ridges—the volcanic lines of relief—the splits of tension through which rock matter had finally overflowed in the closing ages of the cooling crust. The agency which produced tension had ceased, and the interior was shrinking as fast as the exterior. Nothing disturbed the physical peace of the earth save glaciation. But this is a tremendous agency. The distinguished cosmic geologist, Croll, suggests that coal is the result of the vegetation of interglacial periods. One cannot but wonder that if this were so the beds of coal are not much thicker than we find them; but we must remember that bituminous coal may very largely consist of the spores of the various flowerless plants

which chiefly composed the coal forests; that the foliage and trunks of these giant club-mosses (Fig. 10) and the like decayed, leaving fossil remains only here and there; while the less perishable, encased, resinous



Fig. 10.—COAL MEASURE PLANTS.  
*Lepidodendron*, restored, greatly reduced.

spores, gradually built up our coal deposits. On this view Croll's explanation seems perfect. We have only to imagine limitless plains of vegetation in the polar hemisphere luxuriating for thousands of years

without a frost. Then the cold creeps down ; ice caps the pole ; the oceans deepen, encroaching everywhere upon the land ; while clay and other sedimentary material covers the resinous vegetable matter and protects it. Then, again, the axis of the earth reverses its tilt, and for thousands of years the ice melts and disappears, and temperate climate comes once more.

The carboniferous period was rich in limestone deposit. The caustic lime had been slowly turned into carbonate, and this had been dissolved by water and carbonic acid ; then, as the warm water flowed toward the pole which was enjoying equable seasons, it would carry with it the young free-swimming or floating stages of corals, stone lilies and other marine animals which produce limestone rock. As the polar ice melted, the rock thus formed would be elevated into dry land, and would be covered with *débris* such as wind-swept "loess," becoming the bed upon which new coal forests would grow. Thus was a store of energy laid by, almost entirely in one epoch, for the use of a race that may last 10,000,000 years upon the earth ! Ought not this fact to suggest that we should husband our resources for posterity ? The cynic may remark that posterity has done nothing for us ; but when we realise our indebtedness to the past we must feel our obligations to the future.

Let us now consider the carving and grinding

effect of moving ice. As the ice cap gets thicker and thicker it extends above the lower mountain peaks, and as it slides it grinds them off, forming what the geologists call "hogs' backs." The swollen glaciers carve deep grooves in the sides and bottoms of the valleys, while the ploughing boulders which they bear along are also scratched and ground into glacial silt.



*Fig. 11.—MIDDLE SECTION OF GLACIER, WITH STEEP BED.*

(Fig. 11.) From the mountains alongside the sliding glaciers fall immense rocks, which are taken by the glaciers out to sea; and when the glaciers become icebergs and melt, these huge stones are deposited in all sorts of strange declivities in the ocean bed to form gigantic erratic blocks when the sea-bottom becomes elevated into dry land. (Fig. 12.) When, on

the other hand, the glacier melts on land the blocks fall and form great ramparts known as terminal moraines. Still the glacier carves the valley deeper and deeper, carrying forward its *débris* to build still higher and thicker the terminal wall, so that when the glacial period is past and the ice melts, deep lakes



Fig. 12.—ISLAND ON THE COAST OF GEOLOGY POINT, SOUTH POLAR REGION, WITH ICEBERGS.

are left, sometimes on the plains at the base of the mountain ranges, sometimes far up the mountains themselves.

Let us examine and summarise these ice agencies. The eccentric sun produces epochs of about 100,000



years in duration, sometimes closely recurrent. The dates of these epochs are calculable, and furnish us with a geological clock. The last epoch finished some 80,000 years ago; and about 200,000 years ago a still mightier epoch was concluded, having lasted through two periods of nearly 100,000 years each. We must look back nearly 2,000,000 years before we discern another tremendous epoch, and there the power of the mathematician fails us. Looking forward, we learn that another epoch will arrive in about 800,000 years.

These periods of great eccentricity produce in one polar hemisphere long cold winters and short hot summers, and in the other hemisphere long mild summers and short mild winters. In the glacial hemisphere the summer sun is unable to melt all the snow that fell during the previous long and cold winter, and the snow accumulates. The winter is long as well as cold, because, when the earth is distant from the sun, it has so much further to travel in its orbit and it travels slower. Each year there is more and more snow left unmelted, and fogs are produced that make it difficult for the summer sun to act efficiently; then, as the ice piles up, the tropical uprush of hot air travels away from it, causing winds that carry the warm equatorial water into the warm hemisphere. The cap of ice alters the centre of gravity of the earth, and the mild hemisphere is mainly land, while the frigid one is mainly water. For 13,000 years

these agencies act; then, slowly, all is reversed—what belonged to the southern hemisphere now belongs to the northern; another 13,000 years and another reversal happens. The effect of these wonderful changes of environment upon evolution may be pictured by anyone who tries to understand the subject, and the same study explains many puzzling problems in the geographical distribution of plants and animals.

But we must turn from these fascinating speculations to the more prosaic problems of the earth's crust. Let us try to answer several questions. Why is nearly all the land in the northern hemisphere? Why do the great peninsulas point to the south? Why are the lofty mountain chains of the temperate regions carved into deep fiords whose precipitous fronts reach deep into the sea? Why are New Zealand north-west winds hot and dry? These problems and some others must be attacked before we are in a position to understand the origin of the lovely verdant vesture that clothes a great part of the earth's surface.

## CHAPTER VI.

### LAND AND SEA.

A MERELY superficial glance at the distribution of land on the globe, shows that it mainly lies north of the equator. One searches in vain for any explanation, save that the great Antarctic ice-cap has altered the centre of gravity of the earth, and drawn most of the water away from the northern hemisphere. The ice-cap has an area probably over 3,000,000 square miles; its thickness it is impossible to estimate. Judged by the size of antarctic icebergs, it may be miles thick at its margin where the bergs break off; and possibly many times thicker at the pole. This mass of ice must attract the water and deepen the ocean. Were the ice to melt, the water would become much shallower, because it would be drawn to the northern hemisphere, and a great part of the southern hemisphere would be laid bare as dry land. Judging by the soundings of the Antarctic Ocean, we believe that an enormous continent would result. At the same time, were the ice piled high at the North Pole

it would, by its gravitating power, deepen the Arctic Ocean. The land in the north would shrink, Scandinavia would become an island, and large peninsulas would stretch along the Rocky Mountains toward Alaska, and along Eastern Siberia—two peninsulas corresponding with the southern peninsulas terminated by Cape Horn and the Cape of Good Hope. Then, from the shallow southern seas would emerge a huge continent; the same continent which, possibly, some ten thousand years ago was peopled by the race who have left on Easter Island—an islet in mid-Pacific—the cyclopean masonry and gigantic statues that amaze every chance visitant.

If, as suggested, the Antarctic ice-cap be the explanation of the singularly unequal distribution of land in the two polar hemispheres, the great glacial epochs must have produced a still more striking discrepancy—the temperate hemisphere would be an almost unbroken continent, with a few deep seas, but no oceans.

Oscillations of land and sea are not, however, entirely due to the piling of ice at the alternate poles; differences of level are also caused by the crumpling of the crust which results from the efforts of the earth's exterior to fit itself to its shrinking interior, notably, for instance, in such alterations as the simultaneous rising and sinking of opposite coasts of large islands. Again, the crumpling of the cru

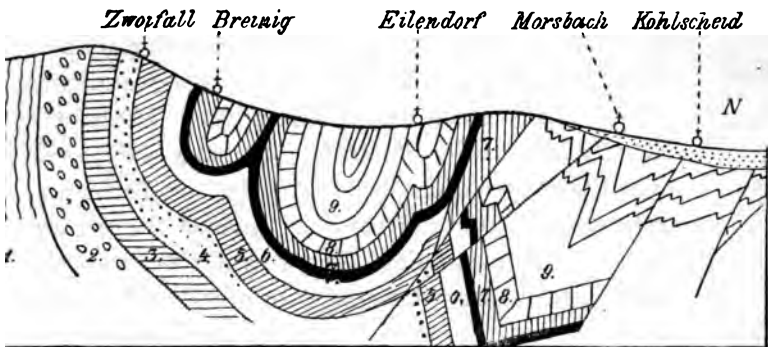
is not merely producing oscillations of land, but is the primary cause of our present volcanoes and earthquakes, the energy of the crumpling being so tremendous as to fuse the rocks into lava, while the action is still further complicated by the explosive and decomposing effects of high pressure steam produced by the inrush of water to heated fissures and vents.

The lateral pressure produced by the crumpling crust acting on strata of different hardness, plasticity, and thickness, results in contortions and "faults" that are almost incredible. Yet recent experiments on confined layers of materials of different hardness and toughness seem to imitate exactly rocks curved into forms as crooked as the letter S. Sometimes strata fold back on themselves; sometimes the rocks split into vast fissures, whose two surfaces slide thousands of feet over one another, until the continuity of the original strata seem lost altogether (Fig. 13); this sliding action grinding the inequalities of the moving faces into powder fine enough to give the rocks the polish of cut gems.

The probable explanation of the wonderful fiords of Norway, western Scotland, western Patagonia, and south-west New Zealand is that these coasts all lie in the path of the anti-trades of which our westerly winds are typical. These winds, becoming saturated in their journey over the ocean, are cooled in ascending mountains, and discharge their moisture,

partly as rain, but largely as snow. This frozen water packs itself upon the mountain-tops; then, being forced downward by the weight of the constantly forming ice, it forms glaciers, which, in a cold period, descend to the sea, cutting the western sides of the mountains into more and more precipitous fiords.

When these winds blow over a very high range of



*Fig. 13.*—DIAGRAM SHOWING CRUMPLING, FAULTS, &C.

Section of the Carboniferous and Devonian, near Aix-la-Chapelle.—  
F. Holzappel. Similarity of number represents identity of strata.

mountains a peculiar phenomenon ensues; the air becomes hot and dry, as exemplified in the New Zealand “nor’-westers.” Let us try and understand this. In ascending a mountain, air expands and does work in lifting the atmosphere above it. To do work requires heat, and so the air cools in expanding. As it cools, the vapour it contains becomes liquid, and in

condensing gives out its so-called latent heat; so, when it reaches the mountain top, the air is not cooled so much as it would have been had it contained no vapour. Then it descends the other side, and the air above it compresses and heats it, and, as it does not take up water again, it becomes hot and dry. If it had been dry when it ascended the mountain, and had produced no rain when it cooled, it would have been equally cooled in ascending and heated in descending; but, because it contained vapour it cooled only slightly in rising and was heated much in coming down again. Hence the New Zealand nor'-west winds, that have had to rise over the range of the Southern Alps, are hotter and drier than they were when they reached the western base of the mountains after travelling across the ocean, and similar winds exist in other parts of the earth.

Besides the physical agencies described, we have the effects of solution and chemical change to discuss. These produce a very interesting set of phenomena: the sculpturing of limestone caves, the growth of stalagmites, and stalactites, petrifications, the disintegration of granite rocks with the formation of clay and fertile soils, the building of silicious terraces such as the beautiful pink and white terraces of New Zealand, the growth of geyser tubes and the marvel of their spouting, and so on. If we grind some chalk

to a fine powder, suspend a little of it in water, and pass a stream of carbonic acid gas through it, the chalk dissolves, and the water is what we call hard. If we wash our hands in this water, it curdles the soap: if we boil it, it leaves a deposit of lime in the vessel. The air contains carbonic acid produced by fires and by the combustion which goes on more slowly but not less really in the bodies of living creatures. When rain falls, it absorbs the carbonic acid, and this water, running through the fissures of a limestone district dissolves the rocks away, and in the course of ages, carves out the extensive limestone caves that are often so very beautiful. Much of their beauty is due to the lime borne by the water having been deposited in translucent masses—called stalactites—that hang from the roof; while corresponding pinnacles—stalagmites—grow by the dropping water leaving its lime on the floor; stalactites and stalagmites frequently lengthening until they meet and thicken into lovely columns. When the water oozes up from the floor of the cave it erects a ring of lime that grows higher into tubes, or widens into basins that form exquisite fountains. When it issues from the cracks in the ceiling it produces curtains of petrified drapery, partitioning one chamber from another. When it flows over plants and through the pores of wood it coats the cells with stone, and makes permanent record of the vegetation of the past.



When it passes out to sea, various molluscs, crustacea, stone lilies, corals, zoophytes, and micro-organisms take it into their bodies and use it, making their exquisite shells or skeletons. These, on the decay of the living architects, go to form fresh beds of chalk and limestone (Fig. 14), that, under conditions of heat, pressure, &c., may crystallise into marble and other beautiful forms of carbonate of lime.



*Fig. 14.*—PART OF A THIN SLICE OF CARBONIFEROUS LIMESTONE.  
Showing that the rock is almost wholly made up of animal remains.

But water-bearing carbonic acid not merely dissolves some rocks; it decomposes others, taking the place of flint or silica. Thus felspar, a constituent of granite, is decomposed into materials such as clay and carbonate of potash, that tend to give fertility to soils in granitic districts. I have seen granitic rock so decomposed in this way that a walking stick could

be driven some inches into it. The silica that is thus expelled by carbonic acid may remain in solution in hot water, to be deposited on the margin of pools, building the pools larger, and growing into such formations as those of the silicious terraces of the North Island of New Zealand destroyed by the eruption of Tarawera. If such hot water ooze out of a hole in the ground it will deposit the silica in a circle, building up higher and higher until the circle becomes a tube with sloping walls of silica. Then, if the bottom heat increases, we have a geyser which spouts when its water comes to the boiling point. The spouting of a geyser is a very interesting phenomenon. After each discharge the water gradually fills the tube, increasing in temperature the lower its position. Owing to the pressure, the water at the bottom gets to be much above the ordinary boiling point. At last it boils and lifts the water above it, then, the pressure being relieved, the surplus heat produces a volume of steam vast enough to blow the entire contents of the tube scores of feet into the air. Geysers are of many different varieties, but the physical principles are practically the same for all.

We have now traced some of the mechanical, physical, and chemical agencies that have aided in moulding and sculpturing the surface of the earth. We shall next consider the living or organic clothing of our planet.

## CHAPTER VII.

### ORIGIN OF LIFE.

DEBATE on the much-discussed subject, the origin of life on the globe, has made but little progress of late years. It has been suggested that, under many special conditions, a meteorite bearing living matter may have plunged through the atmosphere, and may have been deposited on the earth without having developed heat enough to destroy its germs of life. This idea carries the possibility of life one step further back, it does not solve the problem of its origin. There are many problems that transcend the power of the human intellect. It is as impossible to imagine infinity as it is to conceive what lies outside of space. We can neither picture to ourselves eternity nor that which was before time began. Even of the knowable, much is beyond our full understanding. We may peer into infinite space and gain a glimpse of the complexities of matter; feebly we may portray the intricate structure of the single atom, may talk of atoms grouping into molecules, of the millions of

molecules that make up organic cells, of the cells in a single leaf, of the leaves in a forest; but the brain does not truly realise such numbers any more than it does the probability that our one universe would require a hundred millions of millions of worlds to equal the material of its formation. We may see that a complex series of agencies renders an immortal cosmos possible; but the keenest intellectual insight does not enable us to comprehend how the cosmos began.

The beginning of life on the globe may not offer an absolutely hopeless problem, yet the difficulties seem almost insuperable. Until quite recently it was considered impossible to form any organic product; now scores of thousands of compounds of carbon are artificially produced, some of extraordinary complexity, and many of them unrepresented in the world around us. All chemists know the power of electricity in combining elements which are not readily brought into union. It is also easy to imagine the complexity of the play of forces in the earlier periods of the earth's history. But we seem to grope in the dark when we think of the possible causes of the simultaneous formation of many similar complex molecules, and the endowment of these groups of molecules with that power of life which enables them to build up the "living" and complex out of the simple and "dead," to grow at the expense of material

quite different from themselves, to change continually and yet to remain for long periods the same, to multiply their kind, and to adapt themselves to new conditions. While I should be the last to say that certain knowledge regarding the origin of life cannot possibly be attained, I think that, as yet, we have not even found the road which is likely to lead to its discovery.

When we probe into the mystery of things, we find ourselves face to face with four big facts:—Space and time, matter and energy. Geometry treats of the properties of space. By its help we understand the plan of our house, the map of our district, and the geographical globe which shows the configuration of the earth. Then we measure the dimensions of the solar system, and extend our scale to estimate the size of the universe. So vast is the volume that we use the speed of light to compute by. And what is this speed? A flash of light travels far enough to encircle the earth while we blink an eye; it takes eight minutes to reach the sun; it takes over four years to reach the nearest of those others suns, the fixed stars. The collision of dead suns which produced the new star, *Nova Aurigæ*, probably occurred before the battle of Crécy, yet those lightning-speed ethereal waves which told us of the tremendous event reached the earth only a few years ago. Such, then, are the dimensions upon

which the universe is built. But the structure of our universe tells us it was formed by the coalescence of two previously existing universes. The Magellanic Clouds appear to be independent universes; and the mighty cosmos may consist of many universes. The light waves travelling from the sun will reach the limits of our universe in the course of time. And what lies outside this space? More space, possibly boundless space: we cannot conceive of a wall to enclose space, nor can we conceive of infinite space. Our brain power fails us, and there seems no hope that the human race ever will be able to grasp the idea. As of space, so of time. We may think of the events of yesterday, of the Queen's Jubilee, of the aforesaid battle of Creçy, of the period when the earth was a molten red-hot ball, of that collision between primitive bodies which resulted in our solar system, of the birth of the universe; but we cannot get back to the non-existence of time, nor can we picture time's beginning.

As to matter and energy, we know both to be indestructible. Matter forms the body of the cosmos, energy is, so to speak, its spirit, the one never existing apart from the other. We may burn a house, and change solids into gases, but the material of the house exists in the atmosphere, not a thousandth of a grain has disappeared. So with energy; it is as protean as thought, yet as indestructible as matter. The power

of the great ocean steamer seems to be lost; it has been used up in warming the water. We light a fire, its heat forms steam, and the steam drives the dynamo, the dynamo produces electricity, the electricity light, and the radiant energy of the glowing filament is dissipated into space; but all the energy—the power—of the original combustible still remains. We may use the energy of food to throw a stone, it lodges on the roof, and the energy of the food is stored up in what we call potential energy. By-and-by, the stone slips off the roof, perchance upon the head of some unfortunate; the stored energy has become energy of motion. In other words, the potential energy has become kinetic, and the force of the blow tells the individual of its existence. Thus solar energy falls upon the leaf of the tree, and in that wonderful laboratory it tears asunder the locked atoms of the molecule of carbonic acid; the solar energy is stored in the fuel or food produced by the tree; and then, in the bodies of animals, and in fires, the dissevered atoms rush together again, and give us heat and motion once more.

Although the origin of life be hidden from us, very much has been learned as to the possible progress or evolution of the primitive living matter or protoplasm into the present wonderful variety of plant and animal life. Protoplasm, the physical basis of life, is a complex chemical substance containing nitro-

gen, carbon, oxygen, hydrogen, a trace of sulphur, and—often—other ingredients. Carbon and nitrogen are wonderful elements; where all are wonderful these seem most wonderful. Carbon can link itself to carbon in most marvellous fashion; it builds the carbon skeleton of molecules which—clothed with hydrogen, oxygen, and other elements—become molecules consisting of hundreds of atoms whose properties and functions may depend, not alone on their constituents, but on the mode of their building. Thus, butyric acid, which gives its odour to rancid butter, is identical in composition with aromatic vinegar: it is simply the difference in the mode of building that causes the extraordinary physical difference. In its elementary forms carbon is peculiar: packed tight in translucent crystals it is the diamond, the hardest of gems; differently built it is graphite or blacklead, the softest of minerals; aggregated in still another manner it is the common charcoal of our half-burnt forests. Yet as diamond, as graphite, or as charcoal, it will burn and form the gas, carbonic acid, that has so large a scope in the economy of Nature. Nitrogen is a marked contrast to carbon. As an element it is as volatile as carbon is fixed; it never forms strong combinations save with itself; so that whilst other elements produce explosions in combining with different elements, nitrogen produces explosions in parting company



apparently linking with a fellow-nitrogen atom more powerfully than with other elements. It has the extraordinary property of entering into compounds, and keeping mutually-attracting molecules apart, and so forms a constituent of nearly all explosives. In nitro-glycerine it stands separating hydrogen and carbon on the one hand from oxygen on the other; then, when a shock passes through the mass, nitrogen relaxes its weak hold, and the parted elements instantly rush together, the clash of the encounter so heating the resulting gases that a most sudden and violent explosion takes place. In gunpowder it stands sentinel in saltpetre until a spark dislodges it and the explosion ensues—a slow explosion compared to that of nitro-glycerine or its preparation dynamite, because in gunpowder the mass simply burns through, whilst in nitro-glycerine an explosive impulse passes simultaneously throughout the whole mass, and the groups of molecules re-combine at once. So, in the complex protoplasmic molecule, nitrogen is on guard to keep off the attacking oxygen, yet ever ready to give way when it becomes expedient that oxygen shall enter and the molecule be required to perform its work in the economy of organic life.





## CHAPTER VIII.

### PLANTS AND ANIMALS.

**A**LTHOUGH the origin of life is practically a sealed book to us, the processes of life are fairly well understood. Living organisms may be roughly classified as plants and animals. Plants are storers of the sun's energy, and animals re-convert this stored energy into other forms. The plant is thus a fuel former, and the animal a heat engine. Let us consider the matter in detail. Of the flow of radiant energy that is for ever being poured out in such apparently wasteful profusion from the surface of the sun, a minute portion falls upon the earth and warms it. When it falls upon a growing leaf, it does wonderful work. It breaks the bonds that weld together the molecules of combined carbon and oxygen. The welding force is ten times as strong as the most tensile steel, yet, in these wonderful leaf laboratories solar energy sets the atoms vibrating and tears them asunder, liberating the oxygen into the atmosphere.

Then, without permitting the welding force to act, chlorophyll—the green pigment—helps the living matter, in some way not as yet understood, to build the dissevered and other atoms into complex groups. In these the atoms wait, as it were, with folded arms, ready when the time comes to again seize upon their partners, and, as free gaseous molecules, to resume their dance in the sunlight.

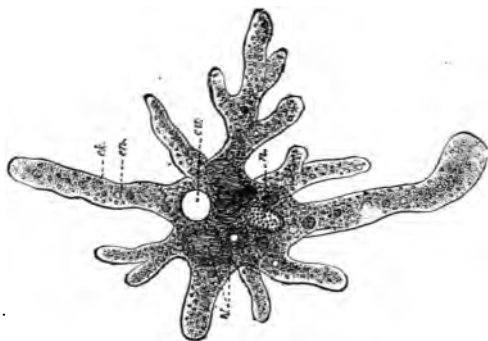


Fig. 15.—AMOEBA.

The ways in which plants and animals obtain and utilise their food are sometimes very complex indeed, and sometimes very simple. One of the single-celled organisms—the amoeba (Fig. 15)—comes into contact with something it can digest; slowly the substance is engulfed or enfolded; then, when all the nutritive material has been utilised, the living cell rejects the useless remainder. Almost as simply the green

particle floating in water absorbs its necessary salts, absorbs its carbonic acid, in the sunlight liberates oxygen, and builds up the complex out of the simple, just as the giant tree in the forest does. The sharp line that, with complex organisms, divides the animal from the vegetable, loses distinctness as we descend

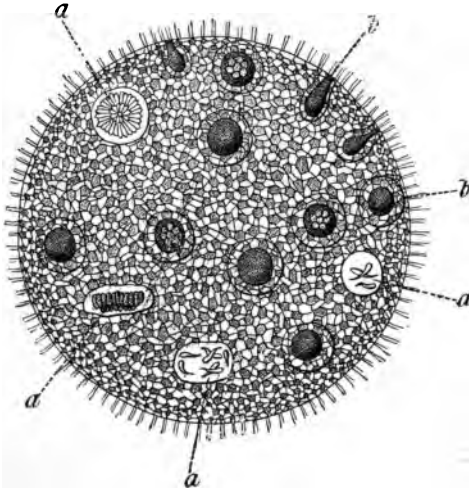


Fig. 16.—VOLVOX GLOBATOR.

in the scale of complexity, until it becomes hard to tell which is animal and which is vegetable. Even the fact that green plants are able to utilise carbonic acid as a source of carbon-supplies, does not always help us, for there are animals with chlorophyll, and

there are plants, like mushrooms, which are not green. Many an animal remains fixed in its habitat, especially during one stage of its existence; many simple plants, such as *Volvox globator* (Fig. 16), spin and travel in the water as full of apparent animal vitality as almost any animal. But it is only with the lowly



*Fig. 17.*—ROOT HAIRS

*h* On the primary root *w*, of a seedling of the Buckwheat; *hc* hypocotyl; *c c* cotyledons.

organisms that this fusion of characteristics occurs; the contrast is marked enough higher up. The plant is characteristically a reducing agent, the animal is as characteristically an oxidiser; the plant

stores potential energy, the animal converts this energy into heat and motion; the plant absorbs carbonic acid, decomposes it, and liberates oxygen; the animal uses the liberated oxygen and recombines it with carbon, and this burning develops heat and gives the power of the animal just as truly as the

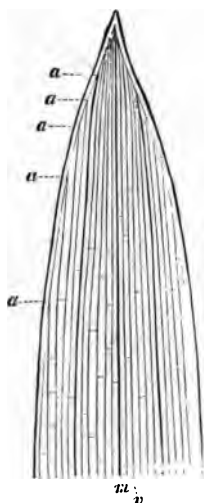


Fig. 18.—APEX OF A GRASS LEAF, SHOWING PARALLEL VENATION.

*m* Middle vein; *a* Anastomosis; *v* veinlets; Monocotyledon.

combustion of the fuel of an engine develops heat which is partly converted into mechanical work.

When we burn a heap of plant rubbish it almost disappears—as gases—into the atmosphere, leaving a mass of light-coloured ashes. All that has burner



away the plant may again get from the air, but the salts that form the ash constituents it must get from water in the soil. To do this it sends out roots with delicate root-hairs near their growing-points (Fig. 17), and, by a peculiar action, these hairs absorb the saline water. From the roots the salt-laden water passes up

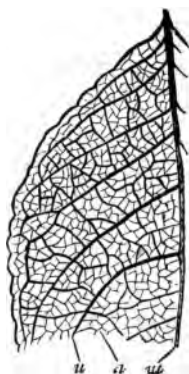


Fig. 19.—DICOTYLEDON.

Portion of a leaf of *Salix Caprea*, with reticulate venation. *m* Mid-rib: *n* the larger lateral ribs; *v* the anastomising veins (nat. size).

the stem of the plant into the leaves, and thus reaches the place where the chlorophyll is spread out in thin layers, and exposed to the action of sunlight. As we go far back in time we seem to see Nature making apprentice efforts—spreading the chlorophyll as a covering to vegetable masses. Gradually more and more perfect methods were acquired, the chlorophyll surface became thinner and thinner, then—to produce

contact with much air, so as to get at much carbonic acid—the parallel-veined plants (Fig. 18) (or Monocotyledons) divided their leaves into thinner and thinner pennants to wave in the sunshine. But Nature, becoming more and more economical of material, began to reticulate the sap-bearing tubes into the complex net (Fig. 19) of the Dicotyledons; then placed the leaf on a thin stem, the petiole, so that the bannerets might flutter as freely in the air as the long streaming pennants of the grasses and palms. With many minor families, flowering plants may be grouped, broadly, as net-veined and parallel-veined. These differ in the number of their seed-leaves (Monocotyledons, with one; Dicotyledons, with two), in the structure and growth of their stems (Figs. 20 and 21), and in many other ways. The early vegetation of the earth was flowerless, and for a long time there were no insects—two facts that must be taken together, since we know that in the majority of our flowering plants the insects carry from blossom to blossom the fertilising golden dust or pollen which converts possible seeds into real seeds. In earlier days, the plants had not “unfurled their coloured flags, to lure winged creatures to their nectar stores.”

And now let us consider the function of the flower. To make the beginning of a new life—whether of plant or of animal—it is required, save with very lowly creatures, and in exceptional cases,

for instance when buds are set free, that there be a union of two elements of different kinds: a sperm-

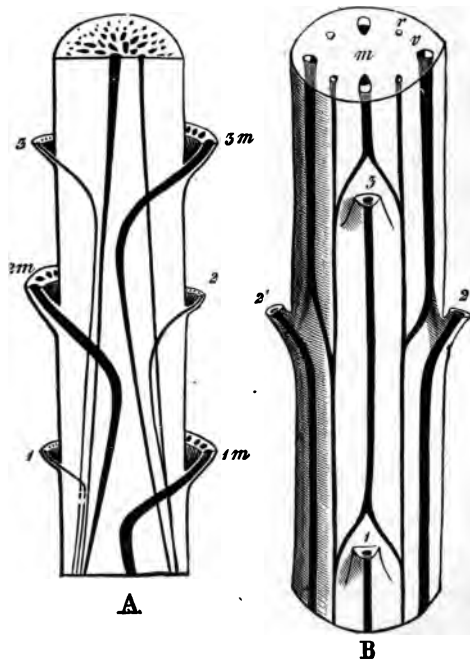


Fig. 20.

Fig. 21.

DIAGRAM OF THE COURSE OF THE VASCULAR BUNDLES IN STEMS,  
IN AN ENDOGEN OR MONOCOTYLEDON.

*a* Longitudinal section through the axis of a Palm stem, showing a transverse section of half of it.

*b* Outside view and transverse section of *Cerastium* hypothetically transparent to show the transparent bundles). An exogen or dicotyledon.

cell or male element, and an egg-cell or female element. Failing union, both die. The male

elements of flowering plants are contained in the pollen-dust formed in the stamens of the flower; the female elements or egg-cells lie within the ovules or possible seeds inside the seed box or ovary, in the central parts of the flower, which are called carpels. Now, it is better for evolution that these male and female elements should come from different organisms. Hence, in pine trees the cones bearing the egg cells are at the tips of the branches, while everywhere throughout the tree cluster the pollen-bearing growths; and so numerous are the pollen grains, that, in the season, when some conifers are struck, the mass of golden dust is wafted by the wind like a cloud of solid sunshine from the tree; so abundant is it that the very ground grows yellow where it falls. Among the many wind-driven wanderers some find egg cells, and the possible seeds or ovules turn into real seed, that is, a young life or embryo develops within. But in the flowering plants this carrying of the fertilising dust is in most cases the work of insects, who, working for their own ends, serve that of plant multiplication at the same time. Many naturalists believe that all the beauty of form, all the brilliancy of colouring, all the wonders of perfume and the sweetness of nectars, have been evolved to attract insects, so that the male and female cells of different blossoms of the same kind may be brought together, and

loveliness and perfection result from the variation in the offspring, due to cross fertilisation.

We may look upon a flowering tree as the highest development of vegetation. It consists of root, stem, branches, and leaves; at a certain season some incipient leaves are modified and become flowers, and parts of these flowers—the stamens and carpels—produce the pollen dust and the ovules, within which, as we have said, there are the male elements and the female elements. The roots hold the tree in its place and supply it with water and salts; the stem is a means of communication, and uplifts the leaves in the air; the leaves use the energy or power of the sunlight to convert the raw materials furnished by water, earth, and air into complex stuffs which go to build up living matter. Part of the manufactured sap of the leaves is carried back to the roots for their nourishment, part goes to thicken the branches and stem, and part supplies the flowers and fruit.

The flower is the organ of reproduction. When perfect, it consists of four whorls of modified leaves. The first whorl is the calyx or cup. It consists of protecting, steady leaves or sepals, generally green, but sometimes coloured, as in the Fuchsia and in the singular Bougainvillea. The next whorl is the corolla, and it is usually to this that the flower owes its beauty. Its parts—called petals—have the function of attracting insects, and they often

protect the more essential parts within from rain and wind, and from unwelcome visitors. The next whorl consists of stamens; rod-like leaves which bear on their tips the anthers, often hanging delicately poised on light filaments. Within the anthers is formed the fertilising dust or pollen which contains the male elements. The central organ, the pistil, has at

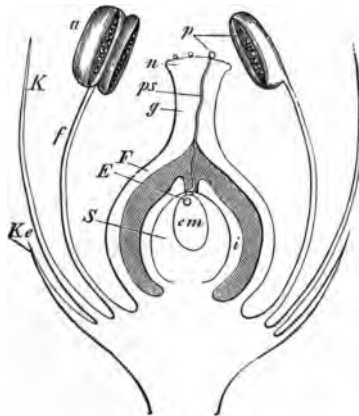


Fig. 22.—DIAGRAM OF FLOWER, WITH POLLEN GRAIN FERTILIZING OVULE.

*Ke*, Calyx; *K*, corolla; *f*, filament; *a*, anthers; *p*, pollen grain; *n*, stigma; *ps*, pollen filament; *g*, style; *F*, pistil; *S*, ovary; *E*, embryo; *em*, ovule; *i*, carpels.

its base the seed-box or ovary, containing the ovules, each of which again contains an egg-cell or ovum. At its tip is a sticky body called the stigma. When a pollen grain falls upon this adhesive surface it is caught, and it begins to send out a filament that

grows and travels through the style—which connects the stigma with the ovary, or seed-box—till it reaches an ovule, which it enters by a small opening. (Fig. 22.) When the male element from the pollen tube unites with the female element or egg-cell within the ovule, the new life begins; the ovule has become a real seed, it contains a young life from which a plant similar to the parent may grow, again to repeat the process. That cross fertilisation may take place, an insect visits the flower, attracted by the perfume or the colour, which indicates that a certain nectar is hidden there. While attempting to sip the sweet juice the insect comes into contact with the pollen, and the little visitor carries this pollen to the pistil of the next flower which it investigates; thus the male elements of one flower fertilise the egg-cells of another. It is interesting to note that many insects, like bees, keep for a time to one kind of flower, for, of course, the pollen of the wild thyme would be of no use if landed on the stigma of the broom.

In flowerless plants, which usually live in water or in damp places, the male elements are actively moving bodies like those of almost all animals, able to seek out for themselves—and in some cases to find—the egg-cells of their kind. This is so in club-mosses (Fig. 23), ferns, horsetails, mosses, liverworts, and in many seaweeds and fungi. In the strange flowering plants called Cycads, such as the Maiden Hair Tree,

similar actively moving male elements come out of the pollen-tube, and make for the egg-cells, thus removing one of the most notable differences between flowerless and flowering plants.

Most complex, most wonderful, are the ways in which the structure of flowers and the structure of



Fig. 23.—LEPIDODENDRON ELEGANS.  
(Coal Plant).

insects are suited to one another. They fit like hand and glove. They present us with miracles of adaptation, especially in the case of some rare orchids, and the rare insects that visit them. But not alone is the flower surprising. Everywhere there is the extraordinary, unconscious ingenuity, in



may say so, by which plants compete with one another, vying with each other in their efforts to absorb the sunlight, to procure the soil-water, to mature and scatter their seeds, having stored therein nutrient material for the early stage of their germination ; then, by prodigal production of such seeds, to secure a chance that every available spot shall be the bed for the germination, growth, and perfection of similar progeny. Yet, though plants present such profusion of wonder, they are far out-done by the organisms it is their duty to provide food for. When we come to consider the perfection of skill, the surprising mental qualities, and the marvellous emotions of the higher animals, we are confronted by facts, each one a miracle. As Walt Whitman said, the mouse can out-stagger sextillions of infidels.



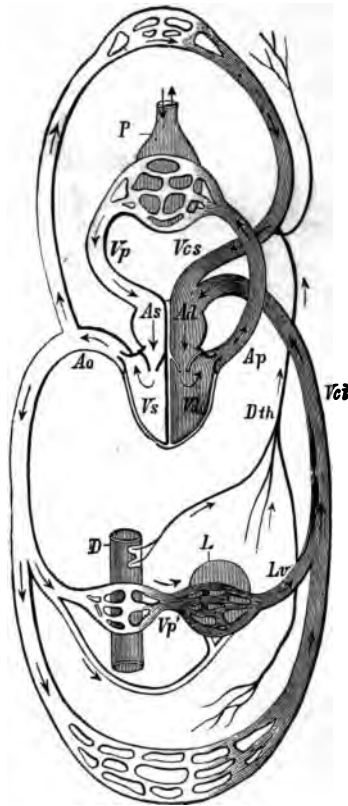


DIAGRAM OF THE CIRCULATION IN AN ANIMAL,  
WITH A DOUBLE CIRCULATION.

(After Huxley).

*Ad* Right auricle; *As* left auricle; *Vd* right, and *Vs* left ventricle;  
*Vcs* superior, and *Vci* inferior vena cava; *Dth* thoracic duct; *Ap* pul-  
monary artery; *Vp* pulmonary vein; *P* lung; *Ao* aorta; *D* intestine;  
*L* liver; *Vp* portal vein; *Lv* hepatic vein.

## CHAPTER IX.

### THE LIFE OF THE BODY.

THE study of development shows an unbroken line of progress from an apparently simple particle of living matter to the most highly-organised animal. The fertilised egg cell divides into many cells, these aggregate into groups, then some of the cells become modified as division of labour sets in. Presently incipient digestive organs appear; then vessels carry the nutritive fluid that is being absorbed; then we find a pulsating heart, the beginning of a skeleton, and a rudimentary nervous system. Special parts become more sensitive to light, to sound, to touch, and the sensory organs are developed. Development still proceeds, and the parts show more and more division of labour, more and more submission to nervous control, until we have a sentient animal with powers of locomotion. Then there are manifestations of emotion, the love of mate, of offspring, of fellows, and finally it may be, of all animate nature; and what is true of the development of the individual, is even more

vividly true of the evolution of the race—the same progress from apparent simplicity to obvious complexity, from the uniform to the manifold, from the latent to the patent, from the potential to the actual. When we come to speak of the varied life in different periods of the earth's history, we shall trace out some of the steps of progress and the relations of the different animals to one another. Our immediate business is to understand the internal life of an animal; and as man is the most perfect representative, let us try to picture to ourselves some of the wondrous adaptations of structure and perfections of function seen in the daily life of our own body.

All animals, including man, are essentially heat engines. They are more, of course, but in one aspect they are heat engines. Almost the whole of a man's energy results from the heat produced by the union of the carbon and hydrogen of the food he eats with the oxygen of the air he breathes. I take a little sugar, dissolve it in hot water, and pour on sulphuric acid—a mass of black carbon results. Sugar is simply carbon united with the elements of water. Sulphuric acid has great affinity for water; if a glass containing a little of it be placed in a cupboard, the cupboard will be kept dry, and the acid increases in bulk so that it often runs over and does mischief. Similarly it takes the water from the sugar and leaves the carbon. Again, I mix

a little chlorate of potash, a salt that contains oxygen, with sugar, and let a drop of sulphuric acid fall upon it; the reaction ignites the mass and it burns vividly, developing intense heat. Exactly as much heat would be developed by the slow combustion of that sugar in the body, and so it is with all food. The fat of mutton makes candles that burn and give light; so also fat burns in the animal, without giving light; the same quantity of heat is produced, only it is diffused through the body. Beautiful indeed is the whole arrangement, involving many steps by which the food is received and ground down so that the most may be made of it; is digested so that it becomes soluble and diffusible; is absorbed into the blood; is carried to all parts of the body to compensate the muscles for what they use up in the combustion which precedes every movement, to feed other structures, and to keep up the necessary temperature. The teeth break up the solid nutriment, and the saliva changes the insoluble starch into soluble sugar. The acid juice of the stomach, containing a ferment, acts upon fleshy or albuminous foods, dissolves them and otherwise changes them so that they are made more useable. The juice of the pancreas, pouring into the beginning of the intestine, attacks all the different kinds of food—starchy, albuminous, and fatty—and makes them useable. Even the waste bile from the liver helps a little. Everywhere throughout the walls

of these organs are thin minute bloodvessels, ready to absorb any food as soon as it becomes soluble and is capable of forming part of the blood. Blood consists of a fluid containing two kinds of corpuscles, or cells, red and white. The red are disc-shaped and very numerous. The white are of all shapes, like the little amœbæ already described. In the healthy body the white corpuscles form a body-guard, destroying—indeed devouring—the disease-germs or bacteria that at times invade the body. The red corpuscles seem to have the power of absorbing oxygen and taking it to all parts of the body; they change colour—when charged with carbonic acid they become a dark purple, and the veins carrying them show as blue lines through the translucent membranes of the skin. The red corpuscles get this oxygen in the lungs, which are two complex bags somewhat like bunches of grapes, the stalks being tubes and the grapes being hollow; the two main tubes join together and open into the wind-pipe or trachea, which opens into the mouth. When we breathe we, as it were, expand the bellows; the ribs rise up, and a cross muscular sheet or diaphragm sinks; so the chest, or box, of the lungs gets larger, and air has to rush down into the lungs to fill the increased space. In every part of the lungs the minute bloodvessels are distributed, and through their thin walls oxygen is taken in and carbonic acid given out; then, when the air in the lung is vitiated, the

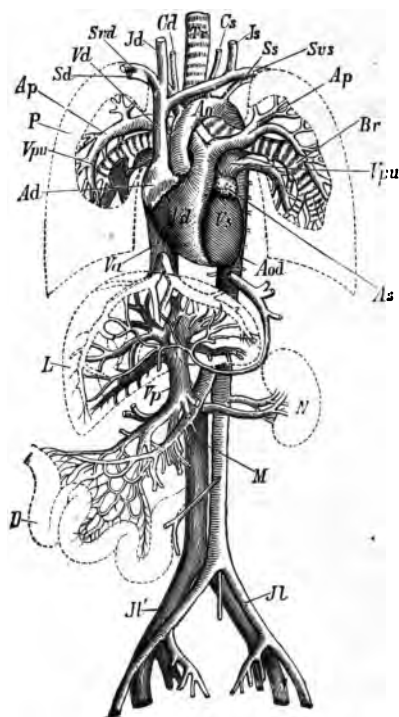
size of the chest is diminished and the bad air is expelled. When, owing to tight-lacing, the lower chest muscles cannot alter their shape, all the work of breathing is thrown upon the ribs, and these but badly perform the double duty.

The blood, then, has its food and its oxygen, and the two are carried to the heart to be forced over the body. The heart is a double pump of four chambers; the upper chambers receive the blood, the lower ones pump it, the right one sending it to the lungs, the left one all over the body; the blood leaves the heart by large arteries, and these divide and divide until they form thousands of small branches or capillaries, then the tubes join and join again until a few large veins carry the blood back to the heart to be pumped to the lungs; and so on, continually repeating the process. It is in the minute capillaries that the work of the blood is chiefly done; through those delicate walls the vital material proceeds to sustain or increase muscles, bones, nerves—in short, all the tissues and cells; through the same walls, in return, passes the used-up material to be taken to the kidneys, the skin, and lungs, thence to be expelled from the system. (Fig. 24.)

The muscles are, as it were, the cylinder and piston of the animal engine; the bones are the crank levers which these move. The muscles consist of countless fibres made up of drum-like cells placed end



to end ; these cells shorten and thicken, and the muscle contracts and the bone moves ; then they relax again, as other muscles contract, and bring the bone back to



*Fig. 24.*—THE CIRCULATORY SYSTEM.  
The letters are the initials of the parts.

its place. Very beautiful are the hinges upon which the bones move. They are often of a ball and socket

character, and allow of a twist as well as of flexion. Then, when we consider the foot, and more especially the hand, the varieties of movement that are provided for seem far beyond the possibility of imitation by the most expert of mechanics. As Walt Whitman said, "a hinge in my hand puts to scorn all machinery." The backbone, which consists of a series of bones or *vertebræ*, is a distinctive mark of the higher animals, so that we speak of the vertebrates and the invertebrates; that is, the animals with a backbone and those without. We shall see later on that, far back in the history of the earth, a little rod called the notochord appeared, which gradually through many ages was replaced by a better substitute, a chain of *vertebræ*.

We have traced the food till it became part and parcel of the muscles, which act on the bony levers and do work; but what urges the muscles to act—what gives the impulse—who are the signalmen that tell the muscles to contract and relax? There is a complete telegraph system, in which a complex gray matter, built into the organ called the brain, acts as the battery, and throughout the body, especially in the spinal cord, which is sheltered by an archway formed by the backbone, there are also subordinate local batteries or ganglia. Passing out of these ganglia and distributed all over the body are little white threads or nerve fibres, arranged in

bundles that give off single threads to the fibres of muscles; just as the strands of telegraph lines give off single lines to the individual houses, these slender threads carry the message that prompts the muscles to act in certain ways. Some of the nerves carry messages outwards from the centre to the muscles; others carry messages inwards from the sense organs to the centres.

The organs of sense—touch, taste, smell, sight, and hearing—put the animal into communication with the outer world. When one thinks of the essential organ of hearing, with the complexities of its membranous labyrinth and its exquisite harp-like “scala media,” then of the marvels of the sensitive retina, the ear and the eye seem very far removed from little groups of cells in which some few are more capable of appreciating the sun’s rays than others, and in which others resonate more easily to the sonorous waves. Yet embryology, palæontology, and comparative anatomy seem to bridge almost every gap of the road from such simple groups of cells to the complex auditory and visual organs. Touch is sometimes extraordinarily developed in animals, and is capable of being highly trained in man, as may be seen in the achievements of the blind. Where touch is most perfect the skin is modified into little papillæ, in which nerves are thickly distributed, ready to take the impression

they receive to the brain or subordinate ganglia of nervous cells. One puts one's finger on a piece of hot iron, the molecules of the sensitive surface vibrate too quickly, the nerves take up the motion, it is transmitted along the minute conducting threads. The central nervous matter of the ganglia receives the message and transmits its orders to the muscles, which contract, and the finger is taken away from the heated mass.

How wonderful pain is! Doubtless the object of existence is joy, and it would seem that the ruling principle is not justice, but love; yet for a maximum of joy we must have pain. Imagine for a moment that pain were removed, we should be useless as logs; if, for instance, burning did not produce pain, we would not dare to use fire. Without that pain no human being using fire would reach maturity with whole limbs. Pain is simply the indicator of a personal error; widespread misery tell of racial error. When these two facts are understood, both pain and misery will be used as little as may be in the economy of life; though we shall not cease to recognise pain as the patient schoolmaster, teaching man the lesson of a fuller and more joyous life,



SENCOTOENIA (East Indian Moth, suffused with purple).



OPHIDERES FULLONICA (Tropical Moth).

The beauty of both due to sexual selection rather than emphasis of contrast for  
 ug. They illustrate well the power of the eyes of insects, to see such detail of

## CHAPTER X.

### THE EYE AND EAR.

**I**F the single window of a room be screened with a sheet of brown paper, and then a hole be perforated in the paper, on the opposite white wall will be seen an inverted picture of the scene in front of the window. Should the sun be shining the effect may be very beautiful. With a large window we get several such pictures by perforating a number of holes, which is a pretty way of showing an eclipse of the sun, every hole giving its own picture of the eclipse. If, instead of merely piercing a hole, we fit a lens of the right focus into a larger opening, the inverted image becomes much more clear and brilliant. The rays coming from each point in an object open outward; when they fall upon a lens the scattered rays are gathered in and converged till they meet, thus every point in an object has a corresponding point in the image produced, and so an inverted picture appears. We call this a camera obscura, and

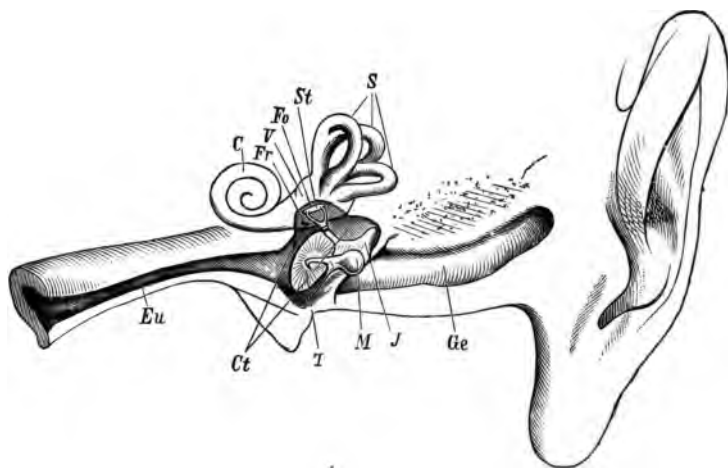
it corresponds with the construction of the human eye. We may conceive how, in the primitive periods of evolution, a sentient hollow might appear on the surface of an organism, then the offspring might inherit the peculiarity, those in whom it was most pronounced coming to the surface of the water to the light, and finding food, and so persisting; then, by continued inheritance, and by the survival of those possessing the peculiarity in the most marked degree, we may picture the hollow growing deeper and more sensitive, till a chamber resulted. Then we may imagine the evolution of a membrane protecting the opening, its thickening till a lens resulted, and so on. Eyes—from the multiple eye of the insect to the single lens eye of the vertebrates—are so various and so different in structure that they have probably been reached by several roads. But leaving questions of evolution to a later chapter of the Romance, let us now try to take an understanding glance at the eye and the ear as they occur in man. The eye is a spherical chamber formed of strong white coating; the interior—except in front—is protected from light by a black membranous lining. At the back of the eye the optic nerve penetrates the membranes and spreads thickly over them. Associated with the nerves are a most complex series of modified cells of wonderful sensitiveness, the more conspicuous being called the rods and cones. The chamber is

filled with liquid and the front part is closed by a firm but transparent lens that has in front of it another lens of liquid, to which shape is given by the horny transparent membrane called the cornea. Between these two hangs a wonderful elastic circular curtain, the iris, that can open and close so as to admit just such an amount of light as will give the best illumination and definition. This curtain opens vertically in the cat-like climbing tribe, and horizontally in the grazing ruminants; while in man the opening, or pupil, is circular. On the sensitive surface of cells and nerve-endings that is called the retina an inverted image is produced by the object in front, the sensitive cells communicate the radiant vibrations to the nerves; these pass the impressions on to the brain, and the sense of sight is complete. When one reflects that these vibrations pour into the eye at rates ranging from 200,000,000,000,000 a second to nearly double this speed, some notion of the wonder of the organ may be gained. Then, when we consider that the lens of the eye must flatten to clearly see distant objects—that differently coloured images focus to different distances, or we should see no white light—when we consider the adjustments of the two eyes to see one object—the adjustment to visual line—the adjustment to varying luminosity—we come to recognise the wonder of the sight.

The vibrations which affect the ear range only from



some 16 to 45,000 to the second, and hence are very slow compared with those of light; yet the ear is an exquisitely complex organ. The outer ear constructed to concentrate the sound waves upon the drum membrane, the chain of minute bones that carry the undulations across the middle ear, and the muscles



*Fig. 25.*—HUMAN EAR.

The letters are the initials of the parts.

to move these bones for the adjustment of the tension of the drum-head to loud or slight noises, are all wonderful. (Fig. 25.) But it is the essential organ of hearing that is the true anatomical marvel. When this organ is intact a tone vibrating the skull bones is heard, though all the outer and middle ear may be useless.

This essential inner ear consists of two parts, the one fitted, apparently, to appreciate all the delicacies of music, the other to estimate direction. If a note be struck on a piano and allowed to die away, and then the loud pedal be held down, on singing this note, and stopping suddenly, it will be found that the piano is resounding to the same note; if a scale be sung, all the notes of that scale will resound on the piano. This fact is dependent on sympathy of vibration, of which resonance is a special example. It may be shown in another way. If one of two tuning forks in unison be vibrated and placed near the other, on clamping the vibrating fork it will be found to have set the other sounding. If the forks be a minute degree out of unison the effect does not occur. This principle of sympathy is of great importance in physical science, and explains the black lines of the spectrum, telling us of the pitch of the vibrating atoms, and hence of their chemical constitution. It probably explains the function of the fibres of Corti of the ear. The fibres of Corti form a kind of harp-like structure consisting of many hundreds of vibrating fibres that are connected with the auditory nerve. It would seem that, to economise space, the series of fibres and nerves are coiled up into a spiral, the whole forming the scala media of the cochlea, each fibre being, probably, tuned to a different tone, and so taking up this tone and

communicating its vibrations to the nerves, to be transmitted to the brain, there to convey the idea of pitch. The idea of direction is probably produced by a series of tubes placed at right angles to each other, and, accordingly, to the direction of the impulse. The vibrations are conveyed through the tubes in different intensities, and therefore affect special nerves; so complex are these tubes and entrances that the whole arrangement is called the membranous labyrinth. The entire essential ear—inside the tubes and between the tubes and the bony walls—is filled with liquid, and thus the sound waves may completely vibrate the membrane; while, in order to do this more effectually, each end of this complex series of tubes has an opening in the bone across which is stretched a vibrating membrane. The chain of bones vibrates the larger membrane that is called the oval window, and this vibration causes the other membrane—the round window—to vibrate also; so the movement is fully communicated to the liquid, thence to the especial receiving structure, thence to the nerves, and so on to the brain. This superficial description of two wonderful organs of sense gives some idea of their structure, but when compared with reflex action, with the brain as a storehouse of impressions—as the organ of thought—and of emotion—the eye and the ear in all their marvellous complexities

appear but stepping-stones to the complete beauty of the organic wonderland.

Let us try to summarise the mechanism of this engine, the human being. Waves of ether enter the eye, waves of air enter the ear; the message of the vibrating atoms shows to the man the form and colour of his surroundings; shows to him, also, the souls looking out of other eyes. His ear enables him to enjoy the myriad voices of Nature and the spoken thought of his fellows. Touch, taste, and smell instruct him in the peculiarities of materials, the suitability of his food, and the healthfulness of his surroundings. All these impulses instruct the brain and other ganglia, and give rise to emotion, to thought, to action. To produce action nerves stimulate muscles, then muscles contract and move bones. The acting muscles must be fed, for motion means wear and tear; the restorer of the wearing muscle is the blood, and the restorer of the blood is the food. Food is fuel; to produce heat and other forms of motion it must be burnt. To burn it requires oxygen, and this—with other constituents of the air—is drawn into the system by the enlargement of the chest. The indrawn oxygen passes through the thin walls of the lungs, and is carried by the red corpuscles to the locality where energy is required to be developed. But food is not fit for animal fuel until prepared and dissolved,

and it is the duty of the digestive organs to do this work.

Wondrous engines! And why do we exist? To get ourselves fuel and water, and to produce—ere we be worn out—other such engines. No other work besides? Surely more is intended! Each engine has far wider possibilities of life and of joy; to appreciate the beauty of music, of song, of oratory, the beauty of form and colour, the glowing sunset, the lovely landscape, the restless sea, the rich complexities of organic life, all the wonder of the world. It is able to vibrate in sympathy with the love of fellows, in joyous comradeship and in the exquisite satisfaction of the service of humanity.





#### CHAMELEONS.

our with their environment. Blinded frogs do not change colour, and fi  
correspond to their fellows, nor to the ground, proved to be blind.

## CHAPTER XI.

### EVOLUTION.

**W**HETHER we study the development and growth of the individual animal (embryology), the history of former animal races—whose remnants we know as fossils—(palæontology), or the comparative anatomy of existing types, we are led to the same great conclusion—that all the different forms are bound together by close or distant relationships. The forms we know are descended from simpler ancestors, and these from still simpler; and as we try to follow the pedigree backwards into the past we find that types now far apart may have had a common ancestor. It is the study of evolution which enables us to form some idea of the connecting links in the great organic chain.

Organisms produce offspring similar to themselves, but not identically the same. The relation between successive generations, which we call heredity, is such that, on the whole, like tends to produce



like; but along with this we have to place the fact of variation. Organisms generally require two parents, and the qualities of both are, as a rule, to some extent reproduced in the offspring, yet often incompletely, and often so peculiarly mingled that we cannot but regard the offspring as a new departure. A single pair generally produce many offspring, it may be thousands. If all the seeds of, say, one foxglove or one poppy, were to germinate, thrive, come to maturity, and produce seed, and this were to go on for some generations, the earth could not provide space for the plants produced. If all the eggs of the conger-eel were to become conger-eels, and reproduce their kind, in a few generations the great sea would not be big enough to contain them. But all germs do not come to maturity. Some seeds germinate better than others; some seedlings are better fitted to survive than others. In springtime, beside the last year's plants, thousands of seedling foxgloves appear; in a few weeks only hundreds show themselves, while a dozen or so are taller and healthier than the rest; soon a few plants monopolise the space—those few that by some slight variation were better fitted to the environment. Consequently the few plants grow to produce seed. This result we call the survival of the fittest, and the process natural selection. There are other agencies at work. One is called sexual selection or preferential mating, when, for instance, a hen-bird

chooses one suitor out of many; it tends to produce the birth of the fit. (Fig. 26.) Then there is what is called artificial selection, the process by which man mates the parents, and so produces various artificial strains or breeds, such, for instance, as the wonderful



Fig. 26.—BIRD OF PARADISE (Illustration of sex selection).

Illustration of sex—male and female bird of Paradise. Contrast of male and female of Paradise bird.

cultivated narcissi and chrysanthemums, the extraordinarily dissimilar pigeons or dogs, the swift racer and the heavy dray horse; each of these being now large groups which originated with a few slight

varieties. So powerful is this artificial agency that almost all organic life is now coming under the influence of man's selection. Thus, we see, there are at least three ways in which certain forms may be selected and others weeded out: by natural selection, which secures the survival of the fittest to cope with its environment; by sexual selection, by which the improvement of the race is helped by the preference given to the superior mates; and by artificial selection, when man chooses forms with special characteristics and produces a breed in which such characteristics predominate.

We must, however, remember that we have not clearly shown the effectiveness of either natural or sexual selection unless we have shown that the process does really tend to select those which have some advantageous life-saving variation distinguishing them from their fellows who are cut off, and does really tend to lengthen and strengthen the life of the survivors, and to favour them further as regards the number and vigour of their offspring. We have also to remember that whilst selfish qualities may tend to the persistence of the single individual, love and sympathy—being welding forces—tend to the success of the group, and hence to its persistence.

The facts of heredity are very wonderful, and are still far from being thoroughly understood. A large family of children may differ most surprisingly; the

characteristics of a great-grandmother will show in one, the father's characteristics in another, or the parental characteristics may be fairly divided among the whole. Sometimes generations of families may be identified by the eyes, sometimes by an intonation of the voice. Characteristics often remain dormant or unexpressed in the inheritance; lie latent for many generations, and then appear again. We are tempted to speak of the vagaries of heredity, but much is explained if it be true that what we inherit as our start in life is not merely a contribution from our two parents, but is multiple, including contributions from grandparents and great-grandparents, and, it may be, forgotten more distant ancestors.

When the body is changed by the influence of use or disuse, or by the influence of surroundings, we call that change an "acquired character," and the possibility of such an acquired character being handed on to the offspring has been often vigorously debated, and there is a decided popular tendency to accept this idea; far greater, probably, than it deserves. To take an illustration: it has long been customary to dock the tails of lambs, yet, although millions and millions of sheep have lived their lives with shortened tails, this acquired characteristic has not been in the least degree transmitted. Inborn qualities are certainly transmitted, but acquired peculiarities scarcely at all. To ascertain the truth on this subject is of

profound—even ethical—importance. If we wanted to produce a breed of short-tailed sheep we should measure the tails of thousands of lambs, and place aside those whose tails were shortest; then, as these bred we should select a few of the shortest-tailed lambs of each generation and breed from them; and, perchance, in a dozen generations, we should have a short-tailed breed of sheep—just as the American farmer bred, within a few years, sheep with long bodies and short legs to suit his bad fences. But there are no facts to show that we should meet with any success if we started in our breeding experiment with lambs whose tails were shorter not “by birth,” as we say, but by having been cut.

The devices developed in plants and animals by selection are wonderful. Animals often take the colour of surroundings, as Polar bears, chameleons, &c. The accompanying illustration of ermine is an example. (Fig. 27.) Moths and caterpillars are the food of birds; presently some are born that taste less sweet than others, and birds—finding this out—do not care to eat them. Perchance the unpalatable caterpillar has a yellow body with a black stripe; the birds avoid the creatures in yellow and black; so these persist and breed, while other caterpillars, differently attired, get devoured. The more striking the appearance and the nastier the taste the greater the chance of persistence, the gaudiness being a kind

of impressive poison label that the birds learn to avoid. Fig. 28 illustrates such gaudiness; possibly sex selections have also helped. But, by and by, among palatable insects of a different species, some appear which by some inborn variation look something like the nasty ones, and those with the greatest



Fig. 27.—ERMINE.

resemblance have a chance of escaping the birds; they have offspring—some less, some more, like—the distasteful caterpillars, &c.; the less like run the greater risk of being eaten by birds, the very like do not get eaten at all. It often takes a very expert naturalist to tell the difference between the unpalatable insect

and the palatable one that has dressed up in a false costume. Little wonder, then, that the birds are also deceived. The wings of these two insects (Fig. 29) are almost exactly alike, yet one is edible but has imitated the distasteful and so is saved.

But there are many other deceptive resemblances which are useful for purposes of preservation. Insects



*Fig. 28.—VICTORIA STENELAS.*  
Brilliant marking, common in South American Butterfly.

get to be like sticks, like leaves, like stones, like twigs; in fact, the range of their unconscious mimicry is extraordinarily wide. The picture of two frogs (Fig. 30) illustrates this well. I was very much surprised once, when picking a rosebud, to see a twig move. I looked and did not notice any difference, so I thought it fancy. Then by accident the twig came

against another bud, and it moved again. I examined it carefully. It was a green caterpillar, so neatly clasping the stem as to be indistinguishable when it stood straight out and perfectly still. On inquiry, I found this to be a common peculiarity of caterpillars belonging to the family of Geometridæ, or measurers,

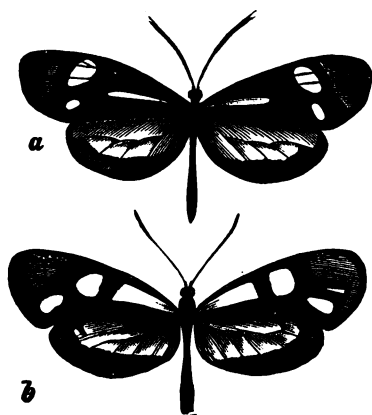


Fig. 29.

*a* *Laptalis Theousë*; par, *Leucousë* (*Pieris*). *b* *Ithomia Herdina* (the mimicked *Heliconius*). (After Bates.)

so called from their peculiar way of walking. They travel by stretching straight out and taking hold by a front grasp, then they let go the back grasp and bring their back legs right up to the front ones, hold by the back legs and straighten again, seeming like



animated inch-tapes pacing the length of the twigs. Obviously such a caterpillar has a much better chance of life than one easily seen. Again, a boy who is a good fighter is generally let alone by those who know it, so deadly snakes often make themselves known as



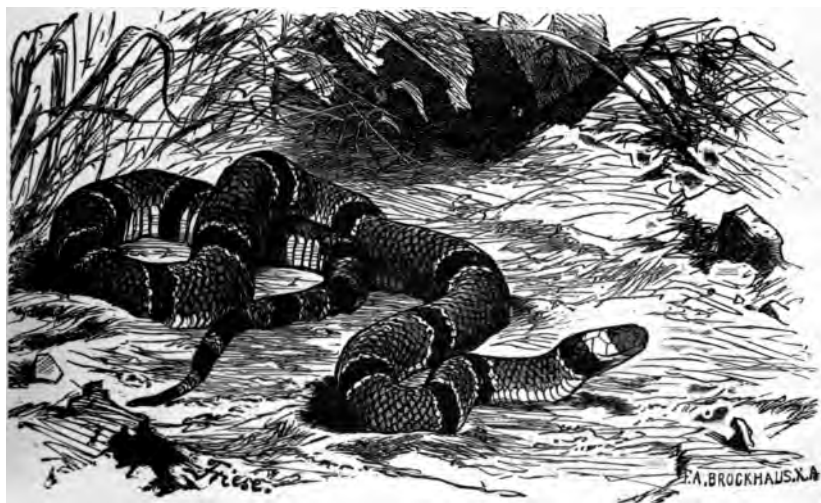
*Fig. 30.—TREE FROGS.*

Change colour—bright green, and green and brown.

the rattlesnake and the accompanying deadly snake. (Fig. 31.)

It is entrancing to study what I can hardly help calling the clever tricks and subterfuges of plants in their efforts to get the most sunlight, the most

carbonic acid, the most of the salts of the soil. They will climb up around a tree, spread out over its crown, and may end by choking the support on whose shoulders they stand. They will adopt all sorts of methods to get their seeds into the soil, will give them wings to travel with, will supply them



*Fig. 31.—CORAL SNAKE.*

The deadly elaps of Central and South America, ringed black and red.

with nutriment to germinate in, will clothe them with sticky material that insects may convey them to a distance, will make their cases explosive so as to scatter them, will give them “legs” that are useful only in the proper germinating weather. Then, how

they outdo one another in lures of bright colour which attract insects! How they develop strength and solidity, or strength and lightness! Look at the wondrous mechanical perfection of a wheat straw as a means of combining a minimum of material with a maximum of strength, see how it coats its outside with a shell of flint when this substance best suits its purpose! But if plants may be in a sense called clever—in result if not in intention—how much more really true this is of animals—when nerves and brain, with emotion and thought, come into play.

Most of the life-saving, life-aiding expedients mentioned are the result of natural selection, but sexual selection appears to have had a not less wonderful influence. Many of the loveliest colours and finest perfumes in nature are its inheritance; the iridescent tints of insects are its production; the gorgeous spreading fan of the peacock, the tail of the bird of paradise, the chameleon-changing hues and the exquisite plumage of other birds—the lovely humming bird, to be seen in the Natural History Museum (Fig. 32), is one of them—the song of the nightingale and the carol of the lark are familiar examples of its work. When the supreme force of love becomes dominant, the conflict of hunger diminishes. In place of the birth of the many to be thinned by rivalry, a few—more fit

—are produced, and the numbers are gradually reduced until, instead of thousands, only one is born.

How wonderful is the progress of passion! First a mere unselective attraction, then a temporary

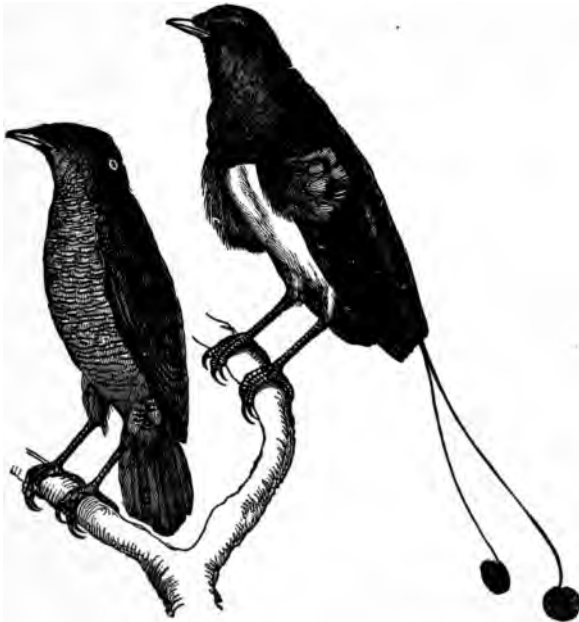


Fig. 32.—CINCINNURUS REGIUS.  
(Male and Female.)

choice, then the union lengthens and a lasting love is born. Wonderful is the broadening and deepening of affection! First the offspring are numerous, and

left to the care of Nature, then maternal love appears, then the parents are united by the same force and the love becomes parental, and we have the animal family with the love of parents and the mutual love of offspring in infancy. Then the love grows more permanent and the love of offspring extends to maturity. With this cementing force, the strength of such unity is so great that a single individual at a birth may more than suffice to keep up the numbers of the race. Still the love extends, and mutual dependence operates, until the family becomes a huge coherent group. Then consensus of action develops language, and language intellect, the two mutually productive and mutually progressive. But before we trace the evolution of these characteristics up to man, we must describe the history of the organic life on the globe, and see how the wondrous processions of plants and animals that have clothed and peopled the earth in its various geological epochs are related to their several physical environments whose history we have already outlined.

## CHAPTER XII.

### ORDER OF STRATA.

LET us think of the many threads that form the warp and woof of this beautiful world, and see how the cards are adjusted, so that each thread may weave into its place in the intricate fabric. How these threads interlock and interweave, numerous as complex, exquisite in their twists and plaits, hard to disentangle! Impact and fire; wind and vapour; ice and water; plant and animal; chemical, physical, and mechanical forces all acting in unison! To some extent we have studied these agencies, and are now in a position to review them with some degree of continuity. In imagination we have pictured the earth as an independent part of a pre-solar system, we have watched the grand conflagration of the impact that produced the sun, and we have seen the earth with the other planets swing into orbits occupying one plane. Then we have imagined the solar nebula, first quickly growing, then, through many ages, shrinking and ultimately becoming the sun. During

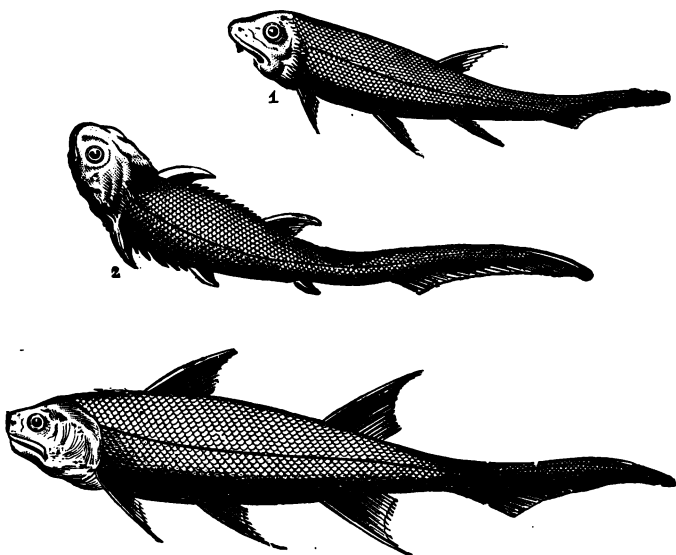
this process the earth has been losing its light atoms and picking up heavy ones—picking up meteoric masses, and amongst them the moon, a meteor big enough to escape the shrinking terrestrial nebula. Then we have seen molecular selection at work, sorting out the atoms—the heavy metallic atoms of gold, platinum, lead, &c., occupying the centre of the mass, the rock material the outside. We have watched the shrinking of the solar nebula, and have observed the earth pick up its atmosphere as it revolved in the outer rare gases of this solar nebula: Then we have watched the gradual condensation into liquid, the cooling of the molten rock surface, the sinking; the production of convection currents, until the rock matter—though still white-hot—was much cooled in its whole depth; the crystallising and separating out of the more infusible minerals, their becoming denser and solidifying, their sinking and silting up the lava seas until the exterior of the earth became a roughly granular mass whose interstices were filled with molten rock of a lower fusing point than the crystals. Then, when the silting reached the surface, the crust completely but irregularly solidified, forming granite, and being irregular from many causes, amongst them the meteoric state of the whole solar system. Meteors frequently came plunging through the crust, possibly trains of meteors helped to cause inequalities of contour and of temperature.

Owing to the earth's rotation and other causes the silting would be irregular, causing lava seas, and the rain of incandescent salt would also tend to increase and produce molten salt lakes. Then, as the atmosphere cleared, the poles would cool, and, presumably during a glacial epoch, organic life would appear at one of the poles. Then would come the first great volcanic period—the volcanoes of surface tension. Ice having become possible, the tremendous glacial epoch would begin to increase the complexities of the paroxysm the earth was passing through. And in that strange contention of snow and fire, tremendous torrents and boiling seas, here and there were equable spots—abodes of life in those beginnings which our minds refuse to picture—here and there living creatures would germinate and flourish, would propagate their kinds, would struggle and die! And, with ever-changing environment, evolution would proceed at a rate which artificial selection alone helps us to imagine. Deep down, in the Cambrian and pre-Cambrian rocks, plant and animal remains already reveal to us wondrous complexity (Fig. 33); yet, probably, the Cambrian layer was deposited during the first volcanic period, that of surface shrinking. Then, after many inconceivably long ages, came the time of the coal measures, when comparative quiet prevailed.

Let us try to familiarise ourselves with the land-



marks of the earth's history. Suppose that the molten matter had deposited the denser and more infusible rocks and minerals, and then crystals with molten matter between had silted up to the surface, and that complete solidification of the interstitial matter had



*Fig. 33.—POLEOZOÛ.*

With single lobed tails before the coal measures. 1 *Acanthodes Mitchelli*; 2 *Chinatus scrutiger*; 3 *Diplacanthus gracilis*.

commenced some 20,000,000 years ago. For ages the process of solidification would extend downwards, the material contracting enormously as it completely solidified. Deeper and deeper the solidification would

extend, the surface growing ever stronger ; then, with continued solidification and contraction, the pressure would increase, and splits—especially far below the surface—would become still more extensive. When solidification had reached down some hundreds of miles, the surface would probably have become cool enough, in places, to admit of the possibility of organic life. And then for ages tremendous erosion would be going on, and presently the rates of surface and interior contraction would correspond. The immense flowerless forests which afterwards produced the coal measures would spread over the comparatively level earth, glacial oscillations submerging the polar hemispheres alternately. This period—when the solar rays decomposed the carbonic acid of the atmosphere and built up gigantic club-mosses, tree-ferns, and horse-tails into forests—may be considered a very prominent land-mark on the historic way. Possibly, until the coal forests liberated the great mass of the oxygen of the atmosphere, animals were fitted to inspire much carbonic acid gas along with the small quantity of oxygen available.

A good deal of limestone was deposited during the carboniferous period ; but most of this material probably existed in the waters of the ocean as soluble bicarbonate of lime. It was probably later, during the great earthquake period of surface crumpling,

that lime was chiefly deposited. Then, too, huge reptiles swarmed in the marshes and in the rank vegetation which was gradually purifying the atmosphere for more advanced organisms. This period—the Jurassic—may be considered the third great landmark.

Rocks may be classified according to the presence or absence of evidences of life. Volcanic rocks, also the granitic and the crystalline changed rocks, called metamorphic, bear no certain evidence of life; but we cannot say that no life existed when these changed rocks were deposited. There may have been many plants and animals then and there, though they have left no trace, for heat and pressure have so altered the rocks as to obliterate all their original structure and make them crystalline. Marble is a crystalline limestone, almost certainly of organic origin, yet its first structure has been entirely changed. Some so-called marbles are masses of beautiful stone lilies, shells of molluscs, &c.

The rock-strata containing undoubted remains of organisms are roughly classified as those of the old and those of the new life, or palæozoic and neozoic. The palæozoic strata are sub-classified, generally, according to the names of the localities where first studied; as, for instance, the oldest are called Laurentian, Huronian, Cambrian, Ordovician, Silurian—when many kinds of backboneless animals

and some fishes flourished. Then follow the Devonian, the age of fishes, the Carboniferous abounding in coal-forming plants, the Permian with many amphi-

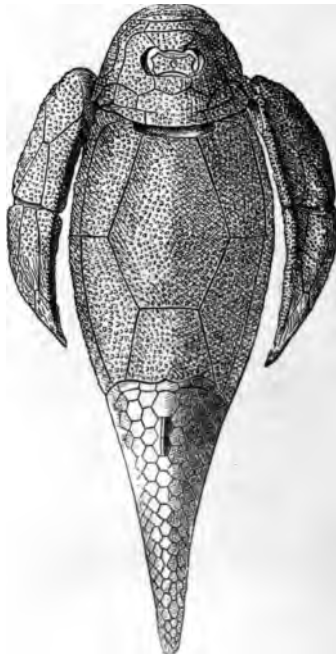


*Fig. 34.*—BASALTIC COLUMNS.

Such as found at Fingal's Cave and the Giant's Causeway.

bians and a few reptiles, though both of these classes began in the Carboniferous. The neozoic systems of strata, often called secondary and tertiary, or mesozoic and kainozoic, include triassic, jurassic, cretaceous, tertiary, and post-tertiary.

All these systems of strata, even the oldest, may be studied on the surface of the earth, where they have been elevated and exposed by contortion and denudation. The basic rocks are granitic; that is,



*Fig. 35.*—PTERICHTHYS CORUNTA.  
Fossils from the Upper Devonian, Old Red Sandstone.

they are rocks in which the dense crystalline **acidic** minerals have been cemented by the **basaltic material** solidifying between them; then, as the **surface cooled**

and shrunk, its pressure caused innumerable fissures, through which the fused basaltic material from below was forced, overflowing above this first deposit. As this cools it often splits into square and hexagonal pillars, &c. (Fig. 34.) These two are volcanic

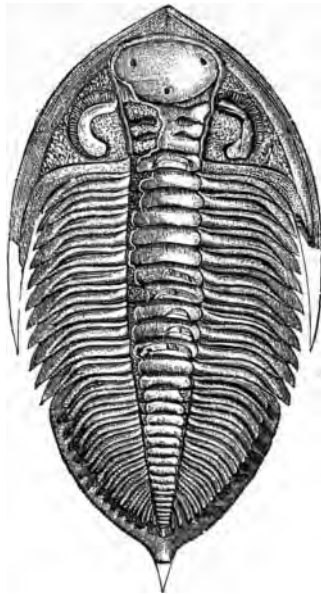


Fig. 36.—PROUTEUS SPECIOSUS (A Trilobite).

rocks. Then come the changed or metamorphic rocks; they were once stratified, but have become crystalline, and contain many valuable stones, ores, and minerals — as slates, serpentine, marbles — and

many metallic lodes. These metamorphic rocks and the volcanic are azoic; that is, rocks in which no trace of life is found. Above them come the palæozoic or old life rocks, with flowerless plants such as horsetails, ferns, and club-mosses; also almost all the chief types of backboneless animals, (Fig. 35) besides not a few lost races, like the trilobites, which have no direct descendants living nowadays. As highly developed organisms like the trilobites (Fig. 36) are found amongst the very earliest life-bearing rocks, such advanced life suggests that the graphitic and other carbonaceous material found in the very old azoic metamorphic rocks consisted at one time of organic growths.

But besides backboneless animals, there were in palæozoic ages many fishes, including types wholly lost from our present day roll of life; amphibians, both small and gigantic, and the beginnings of the great races of reptiles.







JURASSIC FAUNA AND FLORA.

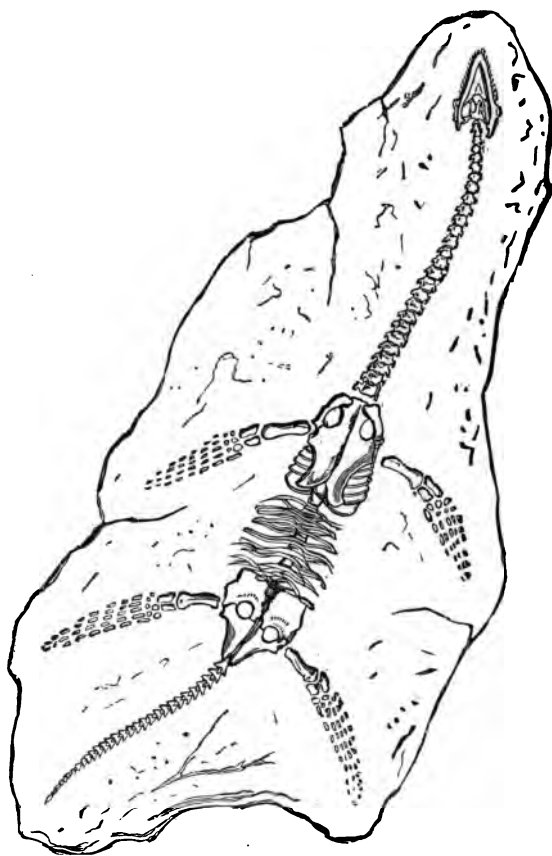
## CHAPTER XIII.

### THE DAWN OF THE PRESENT.

THE neozoic age was ushered in by saurians—reptiles such as the enormous *Megalosaurus* trod heavily the swampy forests; many, such as the plesiosaurs (Fig. 37) and ichthyosaurs (Fig. 38) lived largely in the sea, while pterodauctyls (Fig. 39), or flying reptiles, dragons with bat-like wings, inhabited the air. More and more numerous the saurians became, increasing in size, until, in *Atlantosaurus*, there appeared probably the most gigantic animal that has walked the earth, measuring over 80 feet long and 30 feet high. Some of the fossil foot-prints of the saurians of this period are yards in circumference; their eyes were larger than dinner-plates; while several species were armoured in massive plates of bone which frequently measured fully three feet across.

During the jurassic period birds were beginning to evolve. The first still retained many of the reptilian characteristics. For instance, they had

teeth, and they had long lizard-like tails, each vertebra of which bore quill feathers



*Fig. 37.*—PLESIOSAURUS.

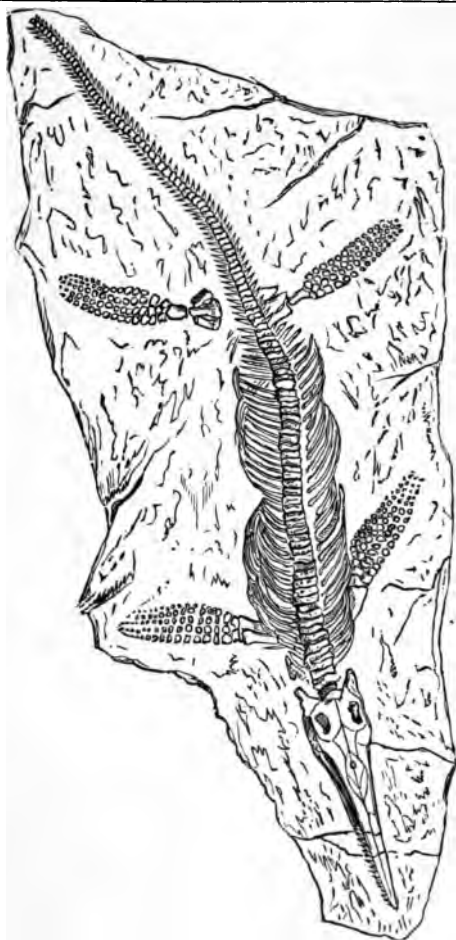


Fig. 38.—*ICHTHYOSAURUS*.

In the University Museum at Oxford are leg-bones of extinct saurians, dug up near by, with the corresponding bones of the existing crocodile attached. Their dimensions average one to ten, in other words the extinct creature would weigh one thousand times the present crocodile.

Far back, in the triassic period, we find the first evidence of mammals. The earliest forms seem to have been related to the duckmole and spiny anteater of to-day—remarkable mammals which lay eggs



Fig. 39.—*PTERODOCLUS SPECTABILIS*.  
H. V. Meg ; somewhat reduced.

as birds do; or to the marsupials, like the kangaroos and bandicoots, in which the small helpless young are carried about for some time after birth in a pouch in front of the mother's body—forms seen in Australia to-day (see Frontispiece, Chap. 8). In the later neozoic

times mammals began to abound. All the while plant life was steadily progressing; flowering plants appeared. Conifers, with naked seeds, had appeared as early as the carboniferous, but the first palms—belonging to the monocotyledons, with a single seed leaf—struggled into existence much later, and did not gain a firm hold of the soil until the jurassic dicotyledons, such as oak and willow, flourished in the cretaceous, and magnolias were then blossoming in Greenland. For a time there continued what we may call a competition between the carrying of pollen by insects and its scattering by the wind, which was necessarily the method until insects gladdened the air, but gradually the insects won the day. Finally the life we are accustomed to behold may be said to have become fairly initiated, though in a very elementary way. Doubtless, the new organisms were the best the environment would permit, for the earth was still physically very different from present conditions.

One lesson taught by science is that there is no blunder in Nature. The ruling power makes no apprentice efforts, though it may seem to do so. Face to face with the mystery of existence, we may reverently look for that sequence of events we call cause and effect, hardly understanding the terms. We find unceasing law, exquisite order. The scientific faith is one of implicit trust in the perfection of the order of nature—down to the minutest detail. No

bad spirits trouble the naturalist; he knows that pain is as necessary as joy; that disease is as important as health; death as essential as birth; the decay of systems as full of promise as their evolution. The mechanism of the whole is perfect, and as we grow in knowledge of it, we grow in trust. Possibly we have mistaken the ruling principle. We have conceived it to be justice; but experience teaches there is something higher than justice. The order of nature seems to be a system in which a maximum of joy is to be attained; a system in which love is the supreme force.

It is very difficult, with our present data, to associate the physical state of the earth with its organic clothing. But it appears fairly certain that many strata were deposited above the coal measures before the great crumpling period set in. Of course, there must always have been wrinkling of the surface. When the first thin skin of solidified granite coated the semi-fluid earth, it must at once have wrinkled with the solidification and contraction of the layer immediately under it, and the molten matter must—as already suggested—have been forced out by the pressure to form basaltic layers. This fluid rock would tend again to level the surface, and this action would probably go on as long as the general surface temperature was appreciably hot. Then, far down in the depths of the rock, the shrink-

age of solidification would tend to proceed at the same rate as the shrinkage of the surface, and a period of quiet would ensue. In the course of ages, the temperature of the surface would practically become constant and surface shrinking would cease, while the heat of the interior would be conducted through the surface. The interior would shrink comparatively rapidly, and the tremendous contortions — the earthquakes and volcanoes that marked the secondary period — would set in, and the paroxysms of surface crumpling would come into play.

Much of the carbonic acid of the earlier period would have been decomposed, and the carbon absorbed by the coal measures, giving to the earth oxygen instead of carbon dioxide gas. This process had to be counterbalanced—fires and animal life were necessary to replenish the stock of combined carbon upon which future vegetation would subsist, so there were gigantic lizards to eat the plants of the period, to use up some of the oxygen, and to give back carbonic acid. The amount of carbonic acid in the atmosphere must still have been very large, and the waters of the ocean must have been nearly saturated with bicarbonate of lime. Molluses, crustaceans, corals, and the minute Foraminifera—so lovely under the microscope—flourished in the seas, gradually converting the soluble limestone into habitations for



themselves, and liberating the excess of carbonic acid into the atmosphere. As these creatures died, they furnished the enormous masses of calcareous deposit which characterise the earlier neozoic period: in the trias, beds of mussel chalk; in the lias, limestones that give us our hydraulic limes, limes with clay in them that form Portland and Roman cement; for the seas were turbid with decomposed granite, and the clay so formed became intermixed with the remains of their myriad inhabitants. Very probably much lime would also be deposited by the escape of the dissolving excess of carbonic acid, much as stalactites and stalagmites are in our limestone caves.

Then, above these lias limes, came—in calmer seas—the oolitic limestones with their peculiar granular structure, to be followed by the vast chalk formations that gave their name to the cretaceous period. Possibly all this time vegetation was fixing more carbon than there were animals to re-combine. Possibly, also, fires ignited by volcanic action, sometimes raged through the forests of this troublous epoch, tending to keep down the stock of free oxygen.

With the passing of the cretaceous period came the full sunrise of the mammalian age, the cold-blooded reptiles retiring—as oxygen steadily increased—before the warm-blooded mammals that suckled their young instead of leaving them to the care of the elements. Thus the association of the warm heart

with abundance of oxygen in the air to aerate the blood seems really to have been needed for the evolution of the higher phases of life.

Above the cretaceous we come to the epoch of tertiary rocks, sometimes called *cainozoic*, or period of recent life, where the forests become leafy, when grass began to cover large stretches of the earth, when mammals became the dominant race. In the place of fish-like cold-blooded reptiles we have fish-like warm-blooded mammals, such as whales. In fact, as the deposition of beds of chalk became less important in the scheme of evolution, our own period began its majestic march. Plants progressed in beauty and perfection towards the varied magnificence of our own present flora, mammals increased in intelligence and skill until the anthropoid creature that was the ancestor of man appeared. Then, in the very latest epoch, the post-tertiary, man himself crowned the glorious ascension—man, a creature so recently developed that his remains are found only in the merest skin of the earth—his race in its very infancy!

Thus, in the dim misty past—many millions of years ago—many of the myriad forms of invertebrates and of simple flowerless plants struggled into being. After a while fishes began to multiply in the ocean; ferns, horse-tails, and cycads, clothed the land. Again a while and huge amphibians of frog-like character wallowed in the marshes, giving origin, in the process

of ages, to enormous reptiles. By-and-by reptiles began to swarm, inhabiting the sea, the land, and careering in the air. By-and-by some members of the reptilian stock became warm-blooded, acquired feathers, became birds. In the presence of myriad insects the flowers gradually

“unfurled their coloured flags,

To call the insects to their honeyed store,”

that the precious pollen might no longer be wafted by the breeze to any accidental situation, but might, on the insect's body, be carried from blossom to blossom unerringly. So the naked flower developed towards the loveliness we are familiar with, whilst reptiles gave place to mammals—predatory or herbivorous, solitary or gregarious; and thus we reach the present stage of evolution, which, under the mental guidance of the big, blundering baby—man, promises, when at last he shall safely feel his feet, a rate of progress far surpassing the most active period of the past. Before we can picture this evolution in detail, we must, however, make ourselves acquainted with the marvellous records of past evolution which are revealed by the study of individual development.





ZYGOTIS MARGINALIS—Male (flying), female (swimming),  
 and others. Illustrating a flying insect and its ancestral forms.

## CHAPTER XIV.

### EMBRYOLOGY.

**T**HERE are many reasons for believing that the plants or animals we see around us are descended from simpler ancestors, and these from simpler still, that types now widely distinct may be traced back to a common ancestry, that as the earth grew older, age after age, higher forms of life arose from among the ranks of the lower, and, in short, that the relationships we express in our classifications are those of an actual pedigree. Connecting links, some preserved in the rocks, and others still surviving, bind one type to another; as the striking diagram (Fig. 40) illustrates in the case of the hand and its corresponding members in other animals. Rudimentary organs, like the hidden hind legs of whales, are evidently the hereditary remnants of organs formerly valuable; the same material of bone and muscle, nerve and blood-vessel, is used in the building up of the great variety of limbs which we see in amphibians and reptiles, in birds and mammals; and the development of the

individual often reads like a shortened recapitulation of the steps which we believe to have marked the evolution of the race. There is a very familiar instance of this apparent recapitulation in the life-history of the frog, which passes through several stages of fish-like structure.

The early tadpole state of the frog bears a close

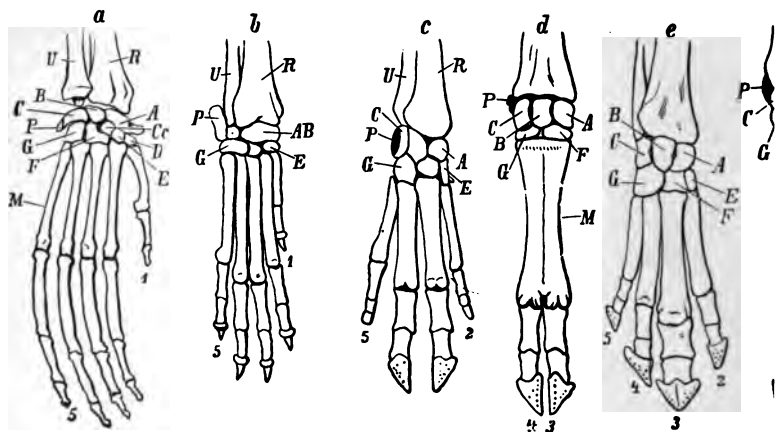


Fig. 40.—EVOLUTION OF SKELETON OF FORE LIMB.  
The same figures and letters refer to similar bones.

resemblance to the tadpole sea-squirt or ascidian, yet the mature frog and sea-squirt are the greatest contrast possible; the one has ascended to be a land-vertebrate, the other has descended far below the structural level of its youth, and lives fixed in its place, secreting considerable quantities of cellulose,

about as degenerate and vegetable-like as an animal may well become. In the early stage, the tadpole frog and the tadpole sea-squirt alike possess the dorsal supporting rod called the notochord, the dorsal spinal cord and brain, several gill-slits opening out

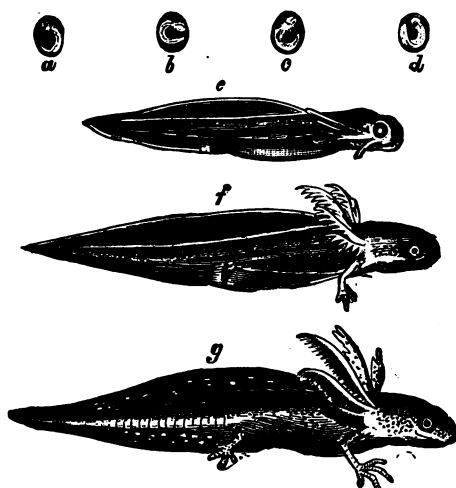


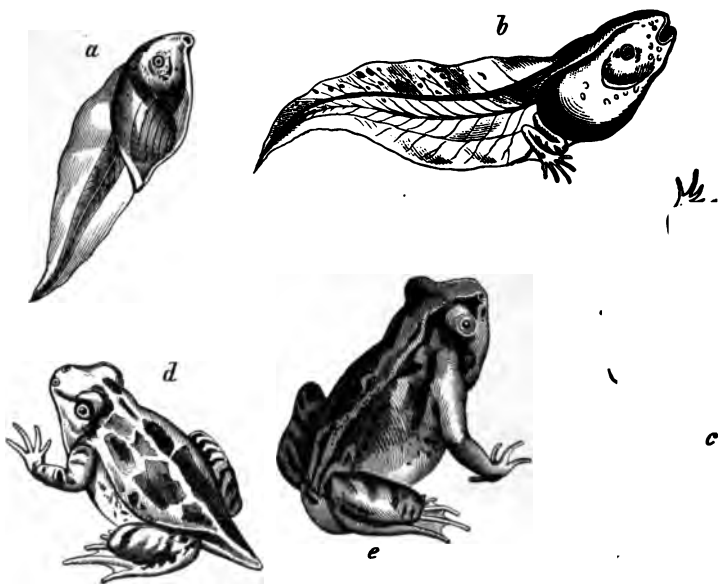
Fig. 41.—EGGS AND TADPOLES OF NEWTS (ENLARGED).

*a, b, c, d* Eggs in various stages; *e, f, g* Tadpoles showing the sprouting of limbs and branchiae.

on the sides of the neck, a simple heart on the ventral side of the body, an essentially similar eye-development, and so on. Compare Fig. 41 of newts with Fig. 42 of frogs. The frog epitomises in its brief life the progressive history of at least millions



of years of evolution. Like the ascidian, it originates from an egg deposited in the water; it rapidly acquires the essential characters of vertebrate structure which we have noted above; by and by it



*Fig. 42.*—STAGES OF A FROG'S LIFE.

shows external gills like a young shark or gristly fish, it acquires the internal gills, the two-chambered heart of an ordinary bony fish, later on it breathes by gills and lungs together like one of the mud-fishes or double-breathers; finally it hops ashore as

a true land vertebrate. Of course it is not by any means an exact recapitulation, only a general recapitulation, but as such it is very suggestive of the truth of the evolution idea. (Fig. 42.)

When we come to those milk-giving animals whose young are born with all the organs fully formed, the wonders of life history revealed in the various stages of growth are most impressive. The eggs of all mammals are about the same size—considerably over a hundred might be laid side by side on a linear inch—the egg of the mouse and of the elephant having almost equal dimensions. Some plants and animals of very low organisation multiply by splitting into two or more parts; some by budding; many by apparently sexless spores; but, as a rule, the life of a plant or animal begins with the union of two cells—the sperm and the egg. When these two come together the egg cell begins to form other cells by cleavage, and a ball, or disc, or sac of cells is formed. (Fig. 43.) For a time the eggs of related living creatures are almost entirely alike, and it is often quite impossible to say of an egg what it will become. As development proceeds, the first hints of the nerve cord and notochord show that the egg is at any rate going to become a vertebrate, a few more characters appear, the limbs bud out, and it is plain that the embryo is that of a mammal, but whether the creature is to be dog,

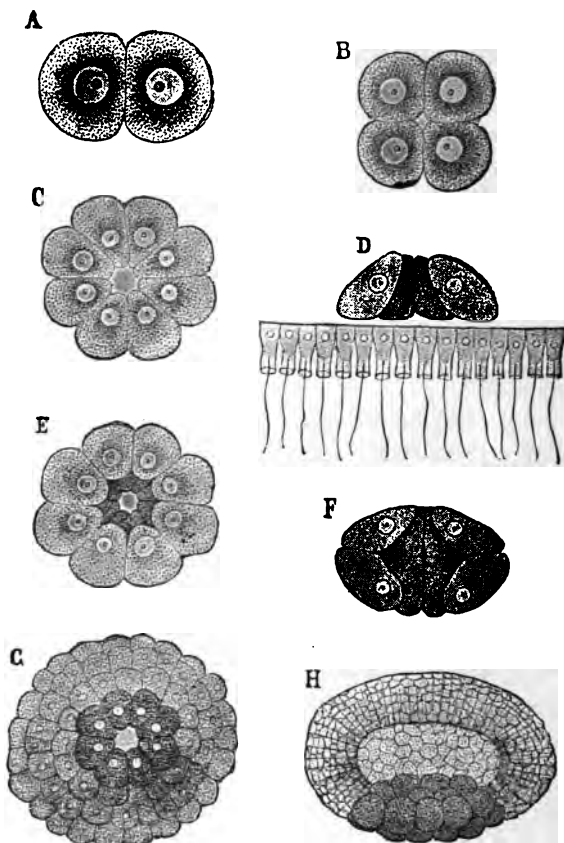


Fig. 43.—CLEAVAGE STAGES OF *SYCANDRA RAPHONUS* (after S. E. Schulze).

*a* Two cell stage; *b* four cell stage; *c* eight cell stage: *d* the same in vertical section in its relation to the collared epithelium of the maternal radium tube (diagram); *e* sixteen cell stage; *f* the same in vertical section (diagram); *g* later state of cleavage with eight granular (ectodermal) cells at the lower pole; *h* blastosphere stage in side view.

monkey, or a man it were difficult to tell. Gradually the later and higher characteristics show themselves, until—from the human germ—the perfect infant is developed, carrying with it the results of millions of years of evolution, now condensed into the brief span of nine months.

Marvellous the evolution of man from the ancestral apparently simple protoplasm! Wonderful the story of his ascent; full of beauty, evoking the most profound reverence, giving hope for the future.

The idea of evolution has ceased to startle the majority of mankind. Doubtless, few can look upon the torch of truth without being scorched by its flare, yet the spirit of honest inquiry is growing. This is also the case with man's place in Nature; so, by all the clues we can find, let us try to trace his history. Where evidence is available, let us employ it fully and fearlessly; where it is missing, let us make firm scientific use of the imagination. These guides have led us through the past section of our romance, confidently though carefully let us follow them through the intricacies of the story still to be told.

Matter and energy are the body and the spirit of the world. Neither can be annihilated, and neither can exist alone—matter without energy would be dead, inert, useless; energy without matter would be a lever without a fulcrum. They fill all space--

protean and infinite. We do not know their real nature, we cannot explain them, but we can study their changes, we can follow the lines of their working in sun and star, in earth and sea, in plant and animal, in man himself. We can to some extent trace out the steps by which, in the great process of "becoming" or evolution, one phase of the order of nature has given place to another. We know scarcely more of the mysteries surrounding us than the infant knows of the great thoughts of the Bible or of Shakspeare. We do not understand, but we do not despair. Standing at the limits of the known, and peering into the illimitable unknown, we are infected with a profound awe and with a mighty reverence by the myriad marvels that lie within the range of our comprehension. Devoutly studying these, we are enabled now and then to venture a step or two into the dimly lit regions beyond.

We see law and order in the intricate mechanism and rapid motion of the powerful locomotive—in the varied loveliness and perfume of myriad flowers; in the swift, strong flight of the royal eagle; in the rosy health of romping children. If, as we look at the locomotive, suddenly there is a loud report, dense clouds of steam rush upwards, and masses of iron are hurled with destructive force in all directions, we say an explosion has occurred—there is weakness somewhere, some carelessness or some treachery. If the

flower fades unexpectedly, we say a cancerous blight or a nipping frost has attacked it. If, while proudly poised in mid-air, the stately eagle in a moment turns over and then falls helplessly to the ground, we wonder and suppose that perchance a rifle ball has struck it. Should the merry play of the children cease and the roses fade from their faces, if they fall prostrate in pain, and become motionless and rigid, and very white and cold, we say the little ones are dead. When all hope of help is past, we arise in our grief to look for the cause of our loss; for the poison berries, it may be, that have wrought our sorrow. Thus science has taught us to acknowledge law and order everywhere, and to search for the chains of cause and effect which run through the whole world.

Although in every direction we may travel until we reach the abyss of the unfathomable, there are also—all around us—the lovely paths of the known. These we may tread with the keenest intellectual pleasure to ourselves and with immense material profit to others. Vast domains have been conquered in astronomy, in electricity, in chemistry, in the other sciences of matter and energy. Slowly the facts of bodily and mental life, in health and in disease, are being made clear. Nor are we without sound hope of discovering the causes which affect the body politic.

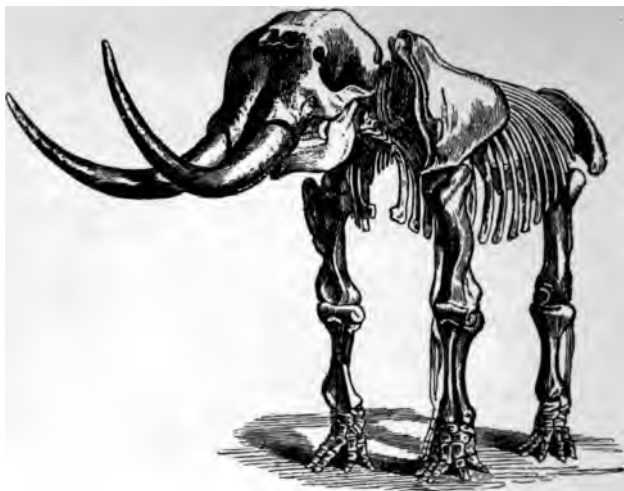
Much that is known is not widely known.

Every thinker, every lover of his kind, should contribute to the great work of student and teacher —should be continually learning and as continually imparting the knowledge acquired, which is like love itself, and

‘ True love in this differs from gold and clay,  
That to divide is not to take away.  
Love is like understanding, that grows bright,  
Gazing on many truths.”







MAMMALS OF THE DRIFT.  
Skeleton of Mastodon.



THE IRISH ELK.

## CHAPTER XV.

### ORGANIC ASCENT.

FROM a single-celled animal to man—from a speck of apparently simple living matter to the interpreter of nature—this is the marvellous ascent we have to contemplate! The seemingly structureless speck is potential with the thoughts of a Newton, the power of expression of a Shakspeare, the music of a Beethoven, with the brain that designed the Parthenon or that gave form to the Venus of Milo; and the inconceivable miracle is attested to us by the record of the rocks, by the development of a child, by the linked chain of existing organisms. Changing environment by prompting variations, which formed the raw material on which selection operated, has caused the potentialities to yield the blush of the rose, the perfume of the violet, the fairy grace of the firefly, and the beauty of human emotion.

Amidst terrestrial turmoil and conflict, fire and storm, eruption and oscillation, some of the tiny specks of protoplasm enclosed themselves within

shells for greater safety. Some of them produced an outer woody layer of cellulose—the material paper consists of. Thus the living unit protected itself, but it also, to some extent, separated itself from fellow particles, and grew exclusive and conservative, and evolved towards the vegetable; while the naked protoplasm, by its very contact with external nature, suffered and joyed, evolved nerve matter and emotion, and the germinal expressions of the higher qualities which distinguish man.

Thus vegetation originated in the cellulose-protected cell, and, aided by chlorophyll, in the dense carbonic acid of early periods, it formed thick-stemmed, leafless, flowerless plants. No leaves were needed to wave in the air and catch such scanty carbonaceous food as exists at present. The air was nearly all carbonic acid, and so the green surface of the succulent stems sufficed for a most luxuriant growth. But, as the aërial carbon lessened, leaves appeared; and at first the leaf-sheaths seem to have tightly clasped the stem as a bad rider clutches the neck of the restive horse. (Fig. 44.) The tornadoes of that wild period would have shaken the broad, reticulated leaf from its delicate petiole. Then, as the carbonaceous food still further diminished, the palms and other monocotyledons lengthened their leaves until they became streaming pennants. By-and-by, with the further decrease of carbonic acid and of hurricanes,

the gracefully-poised leaf of our hard-wood forest came to take its perfect place, and exquisitely perform its intricate functions. (Fig. 45.) Insects had appeared, and with their appetite for nectar and their marvellous instinct for beauty, had sought out the sweetness or colour surrounding the sperm-cells and



Fig. 44.—*TESTUCA PRATENSIS*.

Two lower figures enlarged, the right a spikelet, the left a flowering glume, etc., illustrating a clasping leaf of the present time.

egg-cells, and thus began their unconscious task of conveying the precious dust—the pollen—to the egg-cell waiting within the ovule. Gradually, by interaction, the mechanism became more and more perfect, as perfect, for instance, as in some orchids in which

passage to the nectar is nearly 12in. long, yet not too long for some honey-suckers which have a proboscis of equal length—flower and insect a mutually correlated wonder, telling of the power of evolution to effect the seemingly incredible. Thus the protected cell has

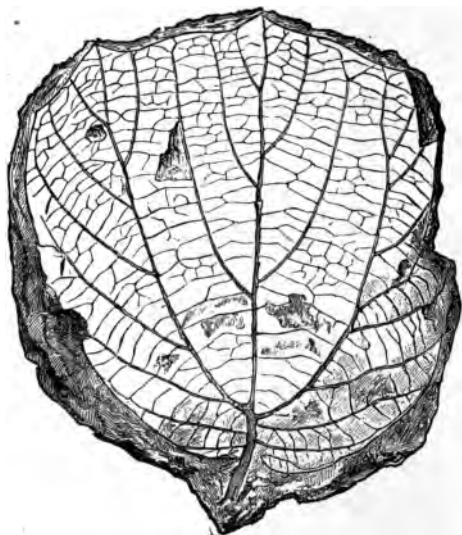


Fig. 45.—FOSSILS OF THE SENONIAN CHALK.  
*Credneria triacuminata*. Hawke.

become the plant in all its varied beauty, and thus the exclusive plant protoplasm—taking energy from the sun and manufacturing the food from which spring joy and emotion—has become the servant of the whole animal kingdom.

But let us return to the naked protoplasm. By contact with surrounding influences the margins of the simple single-celled animal became firm but elastic, and there evolved the interesting creature the *amœba*—hardly to be distinguished from the white corpuscles of the human blood. So much do these resemble each other that the description of one practically serves for the other. The *amœba* is a little independent unit of protoplasm, very simple, and yet not without complex minutiae. It thrusts

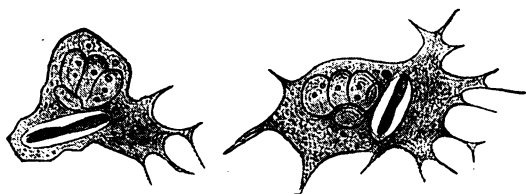


Fig. 46.—A LEUCOCYTE OF THE FROG.

Containing a bacterium which is undergoing the process of digestion; the bacterium has been stained with vesuniue. The two figures represent two successive changes of shape in the same cell (after Melchnickoff).

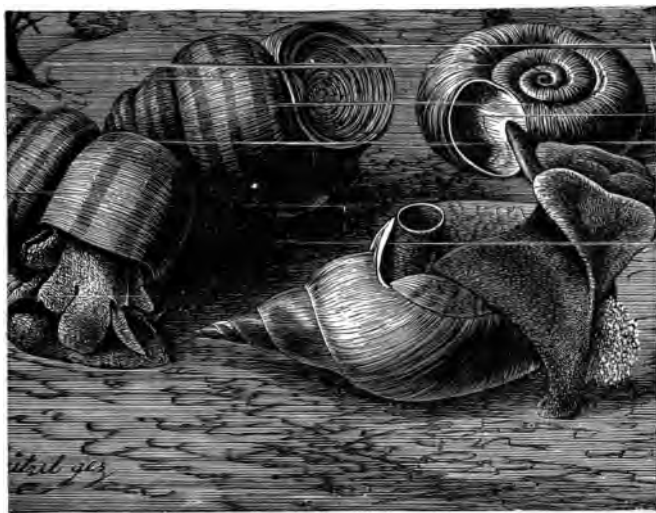
out tongue-like processes—pseudopods, or false feet, they are called; it draws others in on the opposite side, and thus literally flows along. It touches nutritious material and spreads itself over it; it exhausts the nutriment, and rejects the waste. The *amœboid* white corpuscles play the same part in the human body. Myriads of micro-organisms swarm in the air, bacteria and microbes of many kinds—malignant or

kindly. Some of these enter the human system. If the conditions are suitable to them, they multiply, and if they are malignant they soon begin to produce disease; but if the blood be healthy, the white corpuscles gather to the fray, overpower the germs and absorb them, actually saving the body by eating its enemies. (Fig. 46.) If the invading bacteria be very numerous, or the white corpuscles too few or too weak, the micro-organisms kill the corpuscles, then, quickly multiplying, till they number millions, they produce the disease and death of the human organism. How economical nature is! She evolves cells and she uses them to the end. She gives them characteristics like those of the *amœba*; then, in her highest work, she uses those same characteristics. The primitive *amœboid* animal grows complex and clothes its body in flint, in lime, or in horny material, becoming the radiolarians and foraminifers which float in countless numbers on the open ocean or glide in *amœboid* fashion on the sea-floor. Some of the transient outflowing processes become permanent cilia that wave in the water and produce currents, which provide them with food, waft in food, or drive the animals swiftly hither and thither. In the same way cilia wave in the windpipe of the human body, keeping the lining membrane in good condition.

But the single-celled animals formed, by division and clubbing together, colonies of cells, arranged in

spheres, in discs, in tubes, in sacs, or otherwise; and so we reach the sponges, the stinging animals like corals and jelly-fish, the simple unjointed worms, and so on.

The unjointed worms are followed by segmented or ringed worms, like the earthworm, so important in soil-making, and the sand-worms, and the medicinal



*Fig. 47.—A GROUP OF WATER SNAILS.*

*Paludina. Planorbis Corneas. Stagnalis. Limnea.*

leech. On a tack of their own the prickly-skinned star-fishes and sea-urchins developed. On a still higher plane are the jointed-footed animals—crustaceans, centipedes, insects, spiders, and scorpions



which include more different kinds than all the rest of the animal kingdom taken together. Along a quite different path there evolved the bivalves and snails (Fig. 47), and, in some ways highest among backboneless animals, the cuttlefish, with their power-

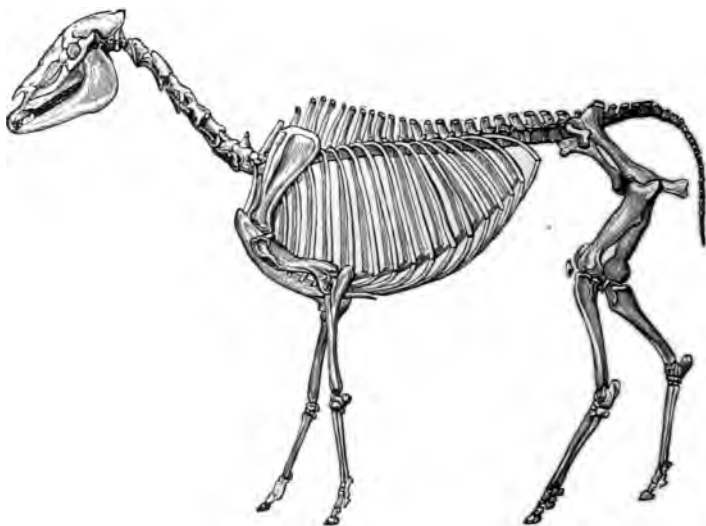


Fig. 48.—HIPPOTHERIUM GRACILE.  
(Reduced one-twentieth).

ful suckers and protective ink bag. The vertebrate ascent begins with the degenerate sea-squirts, and the simple lancelet, which is like a far-off hint of a fish. Through the limbless and jawless hags and amprevs we pass to the true fishes with their

## ORGANIC ASCENT.

---

numerous types. The double-breathing mud with lungs as well as gills, point the way to amphibians, which, as we have seen, are in many respects fish-like in their youth. But from the ancient amphibians, which were the first vertebrates to possess the dry land, sprang the fruitful reptilian

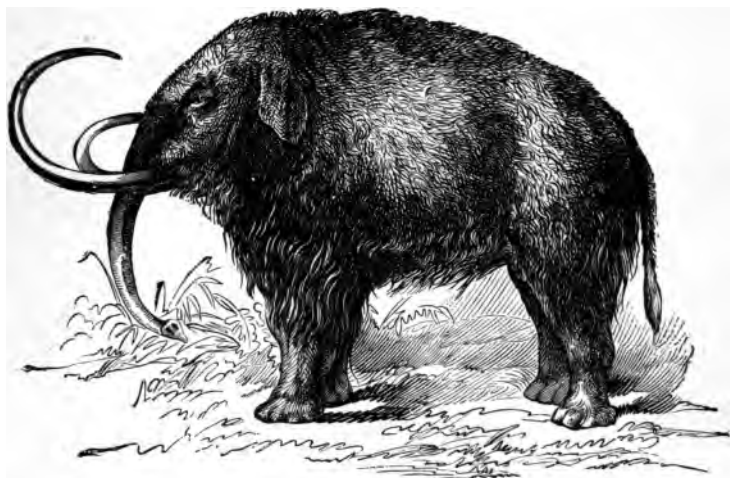


Fig. 49.—THE MAMMOTH *Elephas primigenius*.

stock—lizards, snakes, crocodiles, tortoises, and the numerous extinct saurians—a stock in which both birds and mammals seem to have had their beginnings.

Mammals began with old-fashioned forms—now represented by duckmole and spiny ant-eater, which lay eggs. These were followed by the marsupials or kangaroo-like mammals, in which the young, born

while still very immature, are usually stowed away, fed, and sheltered in an external pouch or cradle. (See Frontispiece, Chap. 8.) Of the higher mammals, in which there is a more or less prolonged connection between the unborn young and its mother, the dominant divisions are familiar to us as the carnivores, the hoofed animals (Figs. 48 and 49), and the monkeys. From among the last arose the unknown ancestors of the higher apes and of man.

Such is the wondrous chain of ancestry that presents an almost continuous process. Links are missing here and there: the rocks are not all investigated, and many creatures seem to have left few vestiges save footprints. But if the rocks yield imperfect record, embryology does not—there the wondrous tale is perfectly told! And is there repulsiveness in the idea of ascent towards perfection? Is it degrading to conceive a constantly improving race?

Such questions are worthily answered in the words of Archbishop Temple:—"It seems in itself something more majestic, more befitting of Him to whom a thousand years are as one day and one day as a thousand years, thus to impress His will once for all on this creation and provide for all its countless variations by this one original impress, than by special acts of creation to be perpetually modifying what He had previously made."





CHAMELEON FLIES AND THEIR LARVÆ.

## CHAPTER XVI.

### THE PROCESSION OF ANIMAL LIFE.

TO an infinite and eternal spectator the progress of the animal world must seem as a varied but orderly procession. In the distant past, it emerged from fire and storm, and for many millions of years it branched and wandered backwards and forwards over the earth—the earth itself a panorama ever shifting from volcano to ice, from ocean to continent, from towering peak to submarine débris. Gradually the algæ and lichens gave place to mosses and ferns, then cycads and palms appeared in their beauty, helping to feed the onward travellers; finally, conifers and forest trees and floral wonders clothed and adorned the scene, and grass was spread as a garment upon the earth. Some species of animals may have marched the whole long journey, but many, especially the larger creatures, failed by the way; they fell out of the ranks, and the earth knows them no more. We have already suggested the trend of the main stream of the procession

that ends with man's human-like ancestor; in "Man in the Making" we shall watch, in greater detail, the royal march to the true human being. But it would be a pity quite to lose sight of some of the many



Fig. 50.—EGGS, LARVÆ, AND COCOONS OF AILANTHUS MOTH.  
Silk worm cocoon in leaf of Ailanthus.

branches of the gorgeous pageant as they diverge to the flitting insect, the soaring bird, the careering horse, the stealthy predatory brute, and the sea mammals so

wonderful in their adaptation to the element which enticed them from the solid land.

When the primary worm-like ringed creatures gave origin to the great stock of insects, the embryonic peculiarity of illustrating past history in present life stages became perhaps more marked than it had been before. All the higher insects, as they hatch from the egg and develop as grub and as caterpillar, present a very worm-like appearance; then,

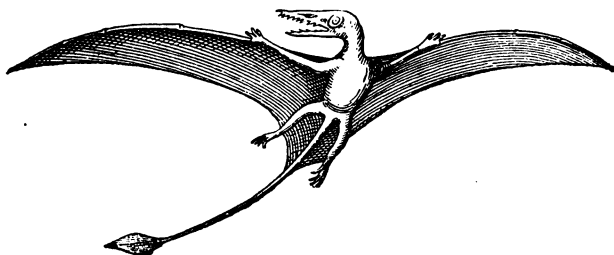


Fig. 51.—RESTORATION OF RAMPHORHYNCHUS PHYLLURUS.  
(Reduced after Marsh).

secluded for a time within a mummy-like case or cocoon (Fig. 50), they undergo a remarkable process of disruption followed by a reconstruction on a new plan. They array themselves in new and wondrous garments, emerging from the temporary retirement of the chrysalis state; even as the erstwhile muffled débutantes emerge from the dressing-room to display their beauty to their waiting world. (See Frontispiece, Chap. 10.) Then those insects whose toilet



has been most exquisitely finished, whose raiment is most certain to win favour, become most successful in mating and most successful as parents. They transmit their inborn charms or superiorities to their offspring, and thus the race advances in beauty. Thus sex attraction helps on the evolution of the insect's beauty of form and colour; and at the same time the flower evolves greater richness of colour, sweeter and more abundant nectar, more powerful perfume—steps of progress which are aided or justified by the necessity of attracting the insect, so that the plant's sex cells shall not be wasted. Sex, which so enriches plant and animal, evolves in another direction into sympathy and love. The self-sufficient amœba develops into the prolific pair; then the mere indiscriminate attraction becomes selective and passion is born; then love evolves—love of offspring and love of mate. Love widens, and sympathy evolves; animals become gregarious, working in consort, and fighting in groups. To consolidate the group, some code of signals is required, and intelligence is evolved; till, in that minute speck of nervous matter—the brain of an ant—a particle far smaller than a grain of mustard seed—there is such miracle of organising force, of love, of sympathy, of emotion generally, that one stands amazed before the microscopic ganglia. To think such a tiny speck of nerve stuff can organise the ant-society to build its federated palaces; to erect stalls for its

domestic animals; to feed and milk them; to organise armies and conduct wars; to use their captured



*Fig. 52.*—*HESPERORNIS REGALIS*, RESTORED.  
Half natural size (after Marsh).

enemies as slaves; to overcome all kinds of obstacles placed to test their capabilities; yet, with such love

of fellows and of offspring as willingly to sacrifice life for the sake of others—for the welfare of the whole! As Darwin said, the ant's brain is, perhaps, the most marvellous atom of matter in the world, where all is wonderful. Wonderful as it all is, the peculiarities of sex-love and group-persistence seem sufficient to account for everything. But the full discussion of these social powers belongs more to the consideration of the evolution of man—in which these factors perform still greater marvels—than to that of the insect world.

So, leaving this tiny yet fascinating section of the grand procession, we pass up the main stream to the diverging branch in which the scaled reptile changed to the feathered bird. The quaint bat-like dragons of the air (Fig. 51) do not appear to have led on to the birds, but there can be no doubt that some other order of the strange extinct reptiles did, though this seems almost incredible when we notice how widely our modern reptiles differ from our modern birds. Reptiles have teeth, they have no wings, their fore-limbs are very unlike those of birds, they are clothed in scales instead of feathers, yet extraordinary links between the reptile and the bird are fossilised in the rocks. We find feathered birds with teeth; creatures almost reptilian in character are clothed in feathers; and reptiles fitted to walk, bird-like, on hind legs (Figs. 52 and 53), complete

the correspondence. It is easy to fancy how the erect deinosauers used their front limbs as flippers



*Fig. 53.*—*ICHTHYORNIS VICTOR*, RESTORED.  
Not quite half natural size (after Marsh).

to increase their speed or their jumping power as many of the flightless birds do now. The

capacity might grow, and grow, aided by natural selection, until a short flight became possible; then the bones lightened, as they did indeed in many extinct reptiles; the muscular energy increased, the temperature of the blood became higher,

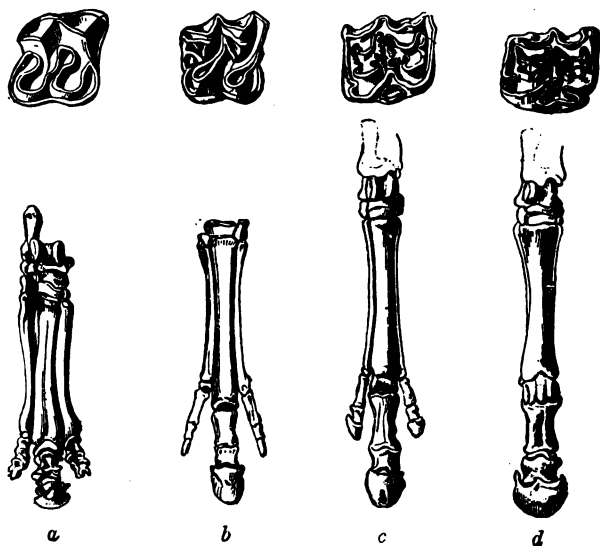


Fig. 54.

Upper molars and hind feet of *a* *Paleotherium*; *b* *Auchitherium*; *c* *Hippotherium*; *d* *Equus*.

feathers formed, and the fore limbs evolved into wings. Then, in the rivalry of the male for the admiration of the female, the useful flight feathers became the gorgeous plumage of the peacock, or

the loveliness of the bird of paradise; and a shrill note was evolved, which competition developed to the happy trill of the canary or the exquisite plaint of the nightingale. Flight is not special to insects, reptiles, or birds, we have flying fish, flying mammals, or bats, &c.; nor are flying reptiles a thing of the past, as seen in Figs. 55 and 56.

Turning from the birds with their young hatched from eggs after these have been laid, pausing for a moment to notice the egg-laying duckmole and spiny anteater, and, at a slightly higher level, the marsupials, which bring forth their young prematurely, and stow them away in the pouch, we regain the main stream of the procession, that of the majority of mammals, which give birth to less immature offspring, which they suckle through a long or short infancy. We find, on the one hand, beasts of prey living individualistic lives, like the lion and tiger; on the other hand, grazing animals living in groups and developing sympathy, giving birth, as a rule, to but one at a time. The predatory competitive creatures gave birth to many, so that they were the more readily thinned by natural selection, and left the fiercest and most cunning as the persistent type; while the co-operative herbivores combined mildness of disposition with unity of action, thus permitting the growth of love and sex selection, which in their turn produced the birth of the fit

and minimised conflict within the species. Thus tusks gave place to teeth for the mastication of green food, and claws gave place to hoofs which would ensure speed.

Then, again, contrast the young of the herbivores with those of the carnivores—notice the stilt-like



*Fig. 55.—FLYING FROG.*

Frogs and lizards that live in trees and can fly, not with wings but with membranes.

limbs of the young within large grazing herds; while the young of the cat or the lion are pretty little compact creatures very differently proportioned from the tall colt, or calf, or lamb. Day-old lambs can run quite rapidly, but the cub cannot even see for several

days after birth. The predatory beast has strong parental instinct, it searches for food for its young, and brings it home to its den ; so long limbs would prove no advantage to its offspring. But with the herbivorous group the offspring must be able to travel with the parents in quest of fresh pastures, else they would be left behind as the flock passed on its journey. So, too, we understand how the cud-chewing or ruminant animal would quickly cut a large quantity of herbage and stow it away in its paunch, then come home to the safe spot selected by the herd, and quietly grind the food it had gathered, fitting it for digestion.

As the marvellous procession marches on, we notice the feet of the ancestral horse gradually evolving from the offensive claw of rapine to the hoof which gives speed. The lower part of the forelimb of the horse corresponds with the middle finger of man, but horses of primitive times had four fingers or toes, then the side ones became smaller and smaller, and finally left but remnants, while the middle finger elongated into the most perfect organ of locomotion in the entire animal kingdom. So the horse saves its skin by flight, though it can give a fairly effective backward account of itself to any adversary. Nowhere is the chain of descent more perfectly demonstrable than with the horse—so perfect, that some of our greatest naturalists have affirmed that it alone is



enough to justify us in regarding the evolutionary interpretation, not merely as a useful hypothesis, but as an established theory. (Fig. 54.)



*Fig. 56.*—FLYING LIZARD.

On the shifting panorama we see the effect of the glacial periods in turning continents into islands and in submerging islands altogether; and we can also see how some of the mammals had to take to water to get fish food, and how they would accommodate themselves to their new element until the whale, the porpoise, the dolphin, and the like competed with fishes in obtaining sustenance in the sea. But these true warm-blooded, lung-breathing cetaceans, fish-like as they may seem, are, of course, mammals, and so they have to come often to the surface and expand their lungs to inhale large stores of the oxygen necessary for their existence.

Thus far, then, have we glanced at the wondrous procession of the evolving animal kingdom, and in a later volume we shall trace the growth of the emotions and other mental qualities characteristic of man.

---

WILLIAM BYLES AND SONS, PRINTERS,  
129 FLEET STREET, LONDON,  
AND BRADFORD.

---



